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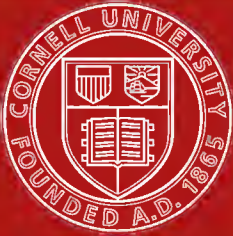
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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF THE COUNTRY AROUND LINCOLN.

(EXPLANATION OF SHEET 83.)

BY

W. A. E. USSHER, F.G.S.,
A. J. JUKES-BROWNE, B.A., F.G.S., AND
AUBREY STRAHAN, M.A., F.G.S.

(IN PART FROM NOTES BY W. H. PENNING, F.G.S., W. H. DALTON,
F.G.S., AND A. C. G. CAMERON.)

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P R E F A C E.

The district described in the present memoir lies partly in Lincolnshire, partly in Northamptonshire, embracing the Vale of the Trent from near Newark to beyond Gainsborough, and stretching eastwards into the country of the Wolds and the wide alluvial plain of the Witham. The city of Lincoln stands not far from its centre. Owing to the direction of the strike, the geological formations cross the district in successive nearly parallel stripes, which run on the whole north and south. The oldest rocks known to exist within the area are of Carboniferous age, but they have only been met with in boring, and this is the case also with the Permian strata found to underlie Retford. Of the Trias there are representatives in both Bunter and Keuper divisions, the former, however, being known chiefly from boring, while the latter covers a wide extent of the Vale of Trent. The Rhætic beds are well shown in the Lea Cutting.

The Jurassic formations of this district are a continuation of those described in the Memoir on Sheet 70. One of their peculiar features in this tract is the absence of the Pecten-bed ironstone, whereby the line between the Middle and Lower Lias becomes undefined. The rock-bed of the Marlstone also dies out south of Burton. Considerable lithological changes are traceable in following the Inferior Oolite, but the Great Oolite maintains its distinctive characters throughout. Again, owing to the absence of the Coral Rag, the line between the Oxford and Kimeridge Clays cannot be satisfactorily traced, and has been indicated on the Map from palæontological evidence alone.

The Cretaceous rocks which rise eastwards into the high Lincolnshire Wolds have at their base the Neocomian Group, which in the so-called "Tealby Beds" present characters that are found in no other part of England. The unconformability supposed to exist at the bottom of the Red Chalk is now found to have no existence; but, on the other hand, evidence has been obtained of a break between the Carstone and the underlying Tealby Beds.

A considerable portion of the district is covered with glacial deposits which present some features of local interest. The boulder-clay, as usual, varies in character according to the sources from which its materials have been derived; the general ice-transport having been here from north to south. Later than the Glacial accumulations are the gravels, which appear to have been laid down by an older River Trent that flowed through the gorge in the Jurassic escarpment at Lincoln. Among the recent deposits also, another of some interest is the blown-sand, which, covering a considerable area, began to drift far back in Post-glacial time.

The economic geology of the district is of some importance. Five horizons of ironstone are known to occur, two in the Lias, one in the Inferior Oolite, and two (but only one of which is worked) in the Neocomian Group. A seam of phosphatic nodules of good quality is of frequent occurrence at the base of that group and similar nodules occur locally in the Carstone also; but in neither case have they yet been worked.

ARCH. GEIKIE,
Director General.

Geological Survey Office,
30th January 1888.

NOTICE.

The survey of Sheet 83 was commenced by Messrs. Penning and Holloway, who examined a portion of the country lying around and south of Lincoln. The area, however, was far from completed at the time of the retirement of the former and of the death of the latter.

The survey was resumed under the superintendence of Mr. H. H. Howell, District Surveyor. Mr. Dalton completed the work commenced by his former colleagues, and carried the lines of the Trias, Lias, and Oolites as far north as a line passing through Clarbrough, Torksey, and Spridlington. The extension of these same beds to the north was examined by Mr. Ussher, whose area was approximately bounded on the east by the River Ancholme. For the mapping of the superficial deposits of some parts of the Sheet, Mr. Cameron is responsible, viz., an area on the east bank of the Trent about Collingham, Eagle, and Kettlethorpe; an area lying south and south-west of Retford; and an area in the valley of the Witham around Bardney, Wragby, and Wickenby.

The eastern part of the Sheet was surveyed by Messrs. Jukes-Browne and Strahan. The former examined the southern part of the Oxford and Kimeridge Clay areas as far north as Stixwold and Dalderby, the eastern part of the Chalk Wolds, and an area of Oxford and Kimeridge Clay lying around West Rasen, Usselby, and Owersby. The Neocomian Rocks and the remaining portions of the Kimeridge Clay area and of the Chalk Wolds were surveyed by Mr. Strahan.

The Memoir has been written by Messrs. Ussher, Jukes-Browne, and Strahan. The first is responsible for the arrangement and general editing of his own notes and of those of his colleagues, on the older rocks up to the top of the Lower Oolites (Chapters i to viii), Mr. Jukes-Browne for that of Chapter ix on the Middle and Upper Oolites, Mr. Strahan for that of the Cretaceous Rocks (Chapters x-xi) and of the superficial Geology (Chapters xii-xiv).

Appendix I. contains a synoptical list of fossils from the Lias and Oolites by Mr. Ussher. Appendix II. a list of well sections, arranged by Mr. Strahan.

The Tables and Lists of Fossils have been revised by Messrs. G. Sharman and C. T. Newton.

A list of publications on the Geology of Lincolnshire has already appeared in the Memoir on Sheet 70.

Two editions of the Geological Survey Map are published, one showing the "Solid" Geology, the other the Superficial Deposits.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, S.W.
25th January 1888.

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Chapters I.–VIII. and Appendix I. have been written, except where otherwise noted, by Mr. W. A. E. Ussher, Chapter IX. by Mr. A. J. Jukes-Browne, Chapters X.–XIV. and Appendix II. by Mr. A. Strahan.

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THE GEOLOGY OF THE COUNTRY AROUND LINCOLN.

CHAPTER I.*

INTRODUCTION.

PHYSICAL FEATURES AND TABLE OF STRATA.

SHEET 83 comprises an area of about 816 square miles. The limits of the geological formations in this area are marked by escarpments or ranges of hilly ground, following the trend of their outcrop. Thus, we find the Keuper Marls forming a range of hills between the western margin of the Map and the River Trent. On the east of the Trent the basement beds of the Lias make a bold feature parallel with the course of the Trent; the continuity of this feature is broken in the southern part of the Map by extensive tracts of low-lying superficial deposits. The Oolitic escarpment forms a marked feature (called the Cliff) dominating the lower lands of the Lias, and exhibiting a rough parallelism with its outcrop feature. In the north-east corner of the Map, to which the Cretaceous Beds are confined, the Chalk Wolds rise above the drift-covered surface of the Upper and Middle Oolite Clays.

The oldest rocks in the area (Triassic Sandstones), being confined to the westernmost edge of the Map, are too limited in extent to show characteristic features.

The greater part of the area is drained by the Witham and its tributaries, the principal of which are the Till and the Bain. The Triassic districts in the western part of the Map are drained by the Trent and its tributaries; and along the north-western margin by the Idle; the north-central district is drained by the feeders of the Ancholme; and the north-east corner by streams which rise in the Wold area.

The most extensive tracts of Alluvium are the fen-lands through which the Witham flows, east of Lincoln, and the Alluvial flats of the Trent and Idle.

The Blown-sand districts flank the eastern margin of the Alluvium of the Trent, and also occur at the foot of the Wolds, extending from Market Rasen northward.

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

The river-terrace gravels form low-lying tracts on the borders of the Alluvium of the Witham and the Trent (south of Dunham). The quartzite gravels between the Trent and Witham, which probably denote the old course of the former river, are confined to the south of the Map. Boulder Clay covers the Oolite Clays in the eastern half of the Sheet, and extends over the northern part of the Liassic area.*

The following is a list of the solid rocks and superficial deposits embraced in the area under description and shown on the Maps:—

			Recent and Post-Glacial		-	{	Alluvium. Peat (partly marine). Fen-Silt (marine). River Gravel and Terraces. Old Blown Sand. Ancient Gravels.
			Glacial		-	{	Boulder Clay. Sand and Gravel.
Cretaceous.	Upper	-	{	Lower, or Neocomian.	Tealby Beds.	{	Middle Chalk. Lower Chalk. Red Chalk. Carstone. Tealby Limestone. Tealby Clay. Claxby Ironstone. Spilsby Sandstone.
	Lower	-		{	Kimeridge Clay. Oxford Clay. Kellaways Rock. Basement Clay.		
Oolite.	Upper	-	{	Great Oolite series.	{	Cornbrash. Great Oolite Clay. Great Oolite Limestone. Upper Estuarine Beds.	
	Middle	-		{	Lincolnshire Limestone. Basement Beds.		
Lower	-			{	Upper Lias.		
Lias.	-	-		{	Inferior Oolite.	{	Middle Lias { Marlstone Rock-bed (Rhynchonella Bed). Clay.
	-	-			-	Lower Lias.	
			Rhætic or Penarth Beds.				
Trias.	{		{		Keuper	-	Marls. Waterstones (?)
{			{		Bunter	-	Pebble Beds.

Besides the strata included in the foregoing table, the borings at Retford and near South Scarle (Collingham) have proved the existence of the following beds:—

Trias { Lower Keuper.
Lower Bunter.
Permian.
Carboniferous.

None of these strata occur at the surface within the limits of Sheet 83, with the doubtful exception of the Lower Keuper Sandstones.

* Further details respecting the physical geography of the district are given in Chap. xii., p. 119.

*CARBONIFEROUS.**

The lowest beds as yet known to exist in this area are the Coal Measures. These were penetrated to a depth of 10 feet by the Scarle boring (*see* Appendix, Wells and Borings), and found to consist of deep-red indurated marls with nodules of hæmatite, similar to the uppermost beds of the Coal Measures of West Nottinghamshire. To what extent the colour may be due to staining from the overlying Permian Beds, and to what precise horizon of the Coal Measures these red shales belong, must for the present remain doubtful. The lamination of the cores showed that the bedding was nearly horizontal, but a dip, imperceptible in the width of half-an-inch, might have a very serious practical effect, and the beds in question may belong to some point in the Carboniferous series lower than the productive Coal Measures.

*PERMIAN.**

The Permian beds of this district are also known only by boring, but have been reached in two cases, at Scarle and at Retford. They consist of argillaceous dolomites and limestones, marls, and sandstones, and are 520 feet in thickness. At the base is a coarse green grit or breccia 1 foot thick, followed by 118 feet of thin-bedded earthy grey limestone of oolitic structure and without fossils. This was at first referred by Profs. Ramsay and Hull to the Yoredale part of the Carboniferous system, and subsequently to the Upper Coal Measures, but in 1879 Mr. E. Wilson pointed out its Permian age in the following words:—†

"Beyond all doubt, the grey earthy *limestones* belong *not* to the Carboniferous, but to the Permian formation, constituting, in fact, with the overlying dark oolitic dolomites and loose sands (?), the Marl Slates; for they are identical with the Marl Slates of West Notts in lamination, colour, and mineral composition, they yield similar obscure plant remains, and a doubtful shell, 'either *Anthracosia* (?) or *Axinus*,' the latter of which occurs in the Notts Marl Slates; like these, too, they occasionally become oolitic; and finally, they are underlain by a coarse greenish grit or breccia, clearly the selfsame bed as that which . . . constitutes the base at once of the Marl Slates and of the Permian formation."

Prof. Hull gives the following analysis by Prof. Galloway of the Magnesian Limestone (Upper Permian):—‡

Carbonate of Lime	-	-	51.2
Carbonate of Magnesia	-	-	38.6
Oxide of iron	-	-	1.7
Clay	-	-	5.8
			97.3

The subdivisions of the Triassic rocks proved in boreholes in this Sheet will be described in the next chapter.

* These notes are supplied by Mr. Dalton.

† *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 813.

‡ *Proc. Inst. Civ. Eng.*, vol. xlix., p. 160 [1877].

CHAPTER II.*

TRIASSIC ROCKS.

INTRODUCTION.

The subdivisions of the Trias which are seen at the surface, or have been proved in borings are as follows :—

Keuper	{	Marls containing gypsum.
		Waterstones (?)—Marls with numerous shaly beds, sometimes arenaceous.
Bunter	{	Pebble Beds.—Buff and red sand and sandstone, with a few quartzite pebbles.
		Lower Mottled Sandstone.—Proved in borings only.

The Triassic rocks met with at the surface, in Sheet 83, consist principally of the Marls constituting the Upper Keuper, but on the western margin of the map, from West Markham, near Tuxford, northward, sandstones or sand-rock beds are occasionally exposed, which have been taken as representatives of the Waterstones, or middle member of the Keuper. The beds attributed to the Pebble Beds of the Bunter, in the adjacent Sheets on the west, enter this Map, but occupy a very small area on the margin of the Alluvium. They contain quartzite pebbles in places. This, however, does not necessarily make them Bunter Pebble Beds, as somewhat similar sandstones with pebbles, at the base of the Waterstones at Nottingham,† are included in the Keuper; but here, having no proof to the contrary, we have taken these Sandstones as Bunter Pebble Beds. The Upper Mottled Sandstone, as in the Nottingham area, is absent, and the Lower Mottled Sandstone not at the surface.

BUNTER.

The following notes are by Mr. W. H. Dalton :—

In the Retford boring, the division into Pebble-beds and Lower Bunter cannot be definitely made out from the terms used in the account, but perhaps the “Red Sandstone, 142½ feet” may be taken as the top of the lower division, whilst in the Scarle boring a marked conglomerate bed of quartzite pebbles has been taken to indicate the position of this somewhat arbitrary division. Still less definite is the subdivision of the Keuper.

Lower Mottled Sandstone.

This series, as shown by the Scarle cores, consists of soft red and brown sandstones, with occasional bands of quartzite pebbles, and here and there seams of red marl. The Retford boring shows only one seam of marl, 3 feet thick, whilst several occur

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

† The Geology of the country around Nottingham (Geological Survey Memoir), 2nd Edition, p. 80.

in the Scarle section. The sandstones were largely disintegrated in boring, and washed out as sand of varying coarseness of grain.

Pebble Beds.

This series consists of soft red and yellow sandstone interspersed with isolated quartzite pebbles and bands of conglomerate of the same material. A bed of red and grey marl, about 16 feet thick, occurred about 200 feet below the top (1,152–1,168, Scarle), and another 3 feet thick at 123 feet from the top at Retford. These are probably lenticular beds of no wide extent. The uppermost beds, where exposed at Retford, are coarse red and yellow sandstones, strongly current-bedded. These were formerly visible in a brickyard north of the canal, at the edge of Sheet 83,* but only the Keuper Beds are now seen. There are, however, very fine sections on Bolham Mill Lane (N.W. of the town), in the cliffs of the Idle. Northward of these, the Alluvium and gravels of that river conceal the outcrop for several miles.

W. H. D.

The thicknesses of the Bunter Beds in the Retford and Scarle borings (*see* Appendix) appear to be :—

	Retford.	Scarle.
Bunter Pebble Beds	451½ feet.	318½ feet.
Lower Bunter	292½ „	223 „

The Pebble Beds have been reached in the Gainsboro' boring also (p. 193), but it is not clear whether their base has yet been touched.

Triassic sandstones similar to those underlying the Keuper Marls at Retford Station occur on the margin of the Alluvium north-west of Clayworth; their relation to the Marls is nowhere observable, owing to a sand-drift, which forms low hills on the margin of the Alluvium where the sandstones are exposed, and also on the west of Clayworth, where they may be concealed by it. The sand-drift occurring so locally in this district and in the immediate neighbourhood of Triassic sandstones might reasonably be referred to their degradation, probably through atmospheric disintegration, but subsequent drifting precludes any reliance being placed on the limits of the sand, as indicative of the relations of the sandstones. The latter may either pass under the Marls or be cut off against them by a north-westerly fault. The conformation of the ground, though doubtless much modified by æolian drift, favours the latter view.

On the hill overlooking the Alluvium near Wiseton Farm on the south east, the sandstones are exposed in two pits. In one, the section consists of 9 feet of pale buff sand-rock or soft sandstone, composed of rather fine quartz grains, more or less worn, with small rounded fragments and patches of red shaly marl with a general linear distribution conforming to the direction of bedding or current bedding. The stratification cannot be proved; if true bedding, it would give a N.N.W. dip of from 5° to 10°. A few small quartz and quartzite pebbles were obtained from the sand.

About 20 yards east from the above, a section 12 feet in depth is exposed, consisting of soft, red, fine-grained sand-rock, flaking off in false laminæ,

* Memoir on S2 N.E., p. 24.

and containing irregular impersistent beds of soft, grey, micaceous sandstone, and thin white streaks, the whole resting unevenly upon pale yellow, yellowish white, and buff sand, with an impersistent band of a pale red colour. The lowest sand exposed is red, the colours being impersistent and not confined to particular beds. The pale yellow sand contains numerous rounded fragments and small irregular pellets of shaly marl exhibiting linear arrangement.

At Wiseton Farm buff and pale brownish soft sand-rock is exposed to a depth of from 2 to 3 feet.

The banks of the canal at the Swan Inn by the high road to Gringley, on the margin of the Map, are composed of red and buff false-bedded sandstones, with fragments of green shaly marl. Three beds of sandstone constitute the section, being each about 4 feet in thickness.

The Rev. T. B. G. Chamberlain, Rector of Wheatley, informs me that the boring at Hayton Vicarage was carried on to a depth of 127 feet before encountering the sand-rock, which was then bored into for 105 feet without obtaining water.

By a new road in the direction of the Ropery, Gainsboro', light reddish brown sand, with a tendency to false-bedding, was exposed under clay and sand of alluvial origin. It is quite possible that this may be Triassic sand. If so, it is either a bed in the Marls, or an appearance of the underlying sandstones due to fault or unconformability.

KEUPER.

Waterstones.

The following notes are by Mr. Dalton :—

The lower division of the Keuper series consists of red and grey sandy marls, with bands of sandstone varying in texture from coarse pebbly grit to fine close-grained freestone, and in colour from brick-red to blue, green, grey, or white; the hardness also varies from compact tough rock to barely consolidated sand. Scanty traces of gypsum occur at intervals in the marly parts.

The chief interest of these beds lies in the abundant supply of water which they contain, and of which the towns of Lincoln and Gainsborough may some day be glad to avail themselves. The outcrop rising from the alluvial level of the Idle at Gringley to 280 feet or more above the sea at Bilsthorpe (about 6 miles west of Caunton, and in 82 S.E.), forms, in conjunction with the westward slopes of the overlying impermeable marls a wide gathering ground, practically free from soluble mineral matter, and affording in the peroxide of iron with which the beds are impregnated a guarantee of the freedom of the water from oxidisable organic matter. The hydraulic pressure under which the water exists in the deeper parts of the series where carried by the dip far below the sea-level, causes it, when tapped by boring through the overlying marls and clays, to rise not only to the surface but considerably above it. At the Scarle boring one feeder from these beds rose in pipes to 52 feet 4 inches above the surface, or about 100 feet above sea-level, and as there is no outlet for the waters to the eastward, this hydraulic level would probably be found constant throughout North Lincolnshire, though the overlying beds rapidly increase in thickness eastward.

No exposure of these beds exists (within the limits of Sheet 83) in the valleys about Tuxford and Laxton, nor in the main outcrop south of the outskirts of Retford. There is an obscure section of sandy marls and sand-

stones in a shallow cutting at White Houses, where the Great North Road crosses the Great Northern Railway, and a small brickyard half a mile north of this shows about 13 feet of mottled marls and coarse yellowish sandstones. A well here is 20 feet deep, probably reaching the Bunter Pebble Beds which are seen in the adjacent railway cutting (Manchester, Sheffield, and Lincolnshire Line) a little beyond the edge of the Map, passing under thin-bedded sandstones and marls, which are mostly obscured by turf.

About three-quarters of a mile north-east of this is the site of the Retford boring for coal, already mentioned several times (*see also* Appendix, p. 194). It is difficult to separate, in the account of this boring, the alluvium formed from the denudation of the marls from the beds which remain unaffected; but this is a small matter, the important point being that the Keuper here extends to 42 feet from the surface. The fall of 30 feet per mile, thus indicated, is not in the direction of the full dip of the Bunter surface, as shown by the head of its outcrop, and consequently the dip exceeds this amount. The dip to the south-east is 68 feet per mile, as shown by the Scarle boring. The resolution of these false dips gives a true dip of 85 feet per mile to E. by S. The above bearings are given roughly, and corrected for calculation.

On the edge of the Map, north of the canal, is another brickyard, showing about 20 feet of the bottom beds of the Keuper and formerly of the Bunter. They consist, as in the railway cutting and the other brickyard, of red and grey marls with thin bands of coarse sandstone ranging from a quarter of an inch up to a bare inch thick. About 20 feet is here exposed.

Similar marl with "tiles" occurs in the grass-grown cutting south of Clarborough.

W. H. D.

The base of the Keuper Marls has been drawn north of Clarborough on the following evidence. In a ditch crossing the lane to Hayton Castle, at a point east of the junction of Black Syke Drain with the canal, a section of shaly marls is exposed to depths of from 6 to 8 feet. The section consists of reddish-brown loam soil, upon dark red loamy and earthy marl in thin shaly bands, with seams of greenish marl and thin layers of brownish and reddish micaceous shale and calcareous stony bands, also thin seams of red shaly indurated loam. These are probably passage beds from the Marls into the Waterstones.

At first sight the beds appear to consist of very fine sandy material, owing to their pulverulent tendency when broken. These beds, which are low down in the Keuper Marls of the district, may or may not represent the Waterstones; their exposure is unique in the areas north of Clarborough and Littleborough.

The sole exposures of sandstones in the area north of Clarborough are on the margin of the Alluvium of the Idle, near Clayworth and Wiseton; unfortunately their relations with the marls are obscured by wind-drifts in this tract, and it is difficult to say whether they owe their position to faults or not.

In the Retford Boring, described above, the upper part for 42 feet is relegated to the Keuper, being made up of—

	Ft.	In.
Soft red marl and sandstone	-	11 6
Upon red and grey marlstone and grey "pumice"	-	30 6

Immediately below this, there are 123 feet of sandstone which form part of the Bunter Pebble Beds.

In the Scarle Boring (*see* Appendix, pp. 194, 195) Mr. Dalton gives 688 feet as the thickness of the Keuper Marls; to which Professor Hull assigned a thickness of 573 feet; these are succeeded by 205½ feet of Keuper Sandstones according to Mr. Dalton, and by 244 feet of Lower Keuper Sandstone according to

Professor Hull. These figures make it probable that Mr. Tomlinson in his account of the Retford Boring has included in the Bunter some beds which ought to be regarded as Lower Keuper.

W. A. E. U.

Keuper Marls.

Mr. Dalton furnishes the following notes:—

The Keuper Marls consist mainly of hard brick-red marl with thin bands of sandstone, sometimes rather coarse, soft and of the same deep colour as the marls, but more generally very fine-grained compact grey, or even pure white, and very hard; in the latter case containing a high per-centage of carbonate of lime. Such bands occur in varying frequency throughout the series, rarely exceeding two inches in thickness, but a zone of sandstone beds several feet thick and divided only by subordinate marls occurs about 60 feet above the base of the series, and is shown on the map by a separate tint, being of some slight economic importance, other less valuable beds being indicated by blue lines. Though rarely of sufficient thickness to be worked now-a-days, this stone was used pretty freely in the past for building and paving, and is still raised in places for metallurgy by-roads. It is too soft for heavy traffic, but hardens considerably by exposure, which permits of the deposition of crystalline carbonate of lime previously in solution in the pores of the stone. The cementing material appears to be wholly carbonate of lime, the rock falling into sand by submersion in hydrochloric acid.

The thinner slabs of stone show ripple-markings and salt pseudomorphs.

There are two principal zones productive of gypsum; that of Newark is near the top of the series, and is represented at Newton, Laughterton, and Gainsborough. The Claxborough zone, on the other hand, is near the bottom of the marls, at the sandstone band mentioned above. The gypsum of the latter horizon occurs not only in the usual form of thick lenticular masses, but also as horizontal and oblique veins, the inosculation of which bind the mass of marl which they penetrate into a species of rock. The fibres of the gypsum are invariably vertical, and therefore inclined at all angles to the faces of the marl which the veins separate. The thickness of the Keuper Marls is about 690 feet, including the grey marls at the top.

Stone is dug for road metal near the road about a quarter of a mile from the south-west corner of the Map. In the lower part of Mather Wood, casual sections show alternations of stone and marl, probably on the same horizon, and forming the upper part of a thick bed of stone quarried at Maplebeck, about two miles to the north-west. The bold escarpment rising from Beesthorpe to Kersall Mill is due to the same rock, though no extensive exposures are seen. A succession of less important features between Kneesall East Wood and Ossington seem by their abrupt disappearance at Norwell Lodge and Newark Hagg Wood to be terminated on the south by a fault, but the escarpment south-east of Norwell shows no corresponding break. If these features mean the course of persistent sandstones however thin, they may be

of value as indicating faults and undulations of the beds. There would appear to be another fault at Hall Field, trending N.N.W. into the Moorhouse Valley, and thence W.N.W. below Laxton. This seems proved by the course of the Laxton sandstone near East Park, below which the depth of the two hollows should reveal inliers of the "Waterstones," whilst at Copthorn we have Keuper Marls of apparently an horizon much *above* the Laxton stone.

Just above Egmanton on the north, the usual regular though slight easterly dip of the beds is changed for one of 7° to the south-west. There is reason here to suspect a fault running from Cock Park to Weston with a small downthrow to the north. The stone here is 3 feet thick under 4 feet of marl. A lower bed of stone is dug, from under 7 feet of marl, on the north of the Alluvium 700 yards eastward from Egmanton church.

Around Tuxford are numerous old stone-pits, and one or two still open. The cutting south of the station is in marls with thin stone slabs; the station well being 48 feet deep in these, and probably reaching the Tuxford stone at the bottom. Some fine examples of pseudomorphs have been found on the stone slabs in this cutting.

The brook north-west of Darlton shows alternations of stone and marl, probably representing the upper part of the Tuxford stone, which forms a dip slope from East Markham.

North of milepost 133 the railway cutting shows strings and veins of gypsum in the lower beds of the sandstone zone. These are merely what the gypsum workers call "rivings" (as riving or separating the rock), and may also be seen at the same horizon on the high road a mile to the west, and in some of the lanes leading down from it in East Markham. Traces are also seen at "The Folly" and near Cleveland House. The railway cutting half a mile west of Askham shows masses of marl and sandstone bound together by inosulating gypseous veins, showing an increase in the amount of gypsum present. Between this and the village is seen a bed of soft red sandstone, massively bedded. "Rivings" are again observable on the hill north-east of Askham.

The railway drains below Gamston Wood show soft red, finely laminated sandstone, whilst the wood itself is on grey marl and sandstone. At Headon gypsum has been raised from beds at a somewhat higher horizon, and at Nether Headon is another old pit in the same.

No sign of gypsum appears in a section of unusual length exposed by the road cutting a mile south-west of Grove, through what appears to be the position of the Tuxford stone, here represented by thin slabs of soft red stone alternating in about equal measure with red marls, each rock being now and then bleached to green-grey by the percolation of surface waters.

Above Little Gringley this horizon again becomes charged with gypsum, which has been extensively worked here. At the hamlet, a small stream shows two beds of stone 8 feet thick, separated by several feet of marl. The feature produced by these is lost to the south, but runs northward to the railway-crossing west of Clarborough Tunnel, but no good stone is seen in the cutting here, only masses of marl bound together by gypseous veins, and forming a mass several feet in thickness, which produces a feature running back at a higher level to Little Gringley (to the gypsum works there), and showing "rivings" in the road cutting a quarter of a mile north of the houses. The feature also continues northward to Clarborough Mill, gypsum being worked at one point in the interval between this and the railway, and at a higher horizon, the beds of which were intersected by the tunnel, on the hill above Clarborough. The cutting east of the tunnel shows only red and grey marls with thin slabs of stone.

On the east of the Trent Valley.

East of the Trent the marls are worked for bricks at North Collingham (and were formerly worked under gravel at South Collingham) and for gypsum on the river bank at Newton, the present cliff intersecting the infilling of old pits with angular masses of hard marl abutting against unmoved material. Gypsum

also occurs north of Laughterton. On the top of the low hills of Keuper Marl at Clifton and Newton, slabs of very coarse grey sandstone occur abundantly, scattered over the fields. As a band of stone of similar character was pierced at about this horizon in the Scarle boring, these fragments probably denote the presence of a bed of stone hereabouts although none such is seen in section.

W. H. D.

A cliff of Keuper Marls with gypsum ramifying through the lower part of the section in veins and sheets, attains a height of 40 feet along the eastern margin of the Trent Alluvium at Dunham Bridge for about 600 yards. Huge tabular masses project from the cliff in places.

A. G. C.

From Marton northward, Keuper Marl forms the high ground bordering the Alluvium and sands of the Trent Valley; its junction with the Rhætic Beds, except in the Lea cutting, is very indefinite, owing to the absence of good exposures and the occurrence of drift-soils.

Between Marton and Littleborough the Marls crop out along an escarpment bounding the Trent Valley, from which their dip-slope, covered by drifted sand, falls gently toward Marton. Where the road to Littleborough Ferry descends to the Alluvium, red marls, mottled green and containing a green marly bed, are exposed. The marls split in tolerably large cuboidal pieces; at their junction with the overlying drifted sands, they break into small pieces, are somewhat indurated, and present an appearance of inosculation, which is probably due to infiltration. Red marls are exposed in the Trent river cliff, on the south-west of Knaith. Red and green marls are shown by the high road at three-quarters of a mile south of Knaith. North of Knaith, red marls have been ploughed up on a tongue of hilly ground projecting into the area covered by blown sands.

In the Lea railway cutting, for five feet downward from their junction with the Rhætic black shales, the Keuper Marls are of a pale greenish tint, due to infiltration, as the Rhætic shales are highly pyritous. The cutting commences at 24 chains from Gainsboro' Station, and shows finely divided red marls, mottled with green spots and irregular streaks, and containing a thin band of whitish sandstone composed of rounded grains. Gypsum occurs in irregular masses and layers mixed with indurated marl of a dark grey colour.

At, and near, Gainsboro' Station, the Marls are well exposed in the railway cuttings, and are associated with irregular masses of gypsum.

Red and green marls have been ploughed up at half a mile east from Gainsboro' Workhouse.

Marls are exposed south of Castle Hill Camp by the road to Morton; they have been turned out of a pond in the valley near Paddocks, and are visible on Castle Hill and on the north of Thonock Grove.

On the hillside north-north-west of Thonock House a marl-pit shows about twenty feet of red marl mottled with occasional green patches and irregular streaks. Impersistent masses of gypsum occur in places, binding dark grey marl in contact with them. No dip was procurable.

West of the Trent.

The following section is afforded by the bank of North Wheatley Brook, where it touches the road to Hayton above the village, in descending order:—

	FT.	IN.
Red loam with irregular patches of grey clay at base	3 to 5	0
Grey loamy clay and marl with broken grey shales and marly beds	2	0
Even ripple-marked pale greenish-grey stony beds with pseudomorphs after rock-salt, exposed in the stream bed	1	0

The upper bed is alluvial, and the uppermost part of the succeeding stratum may be re-deposited.

Under South Wheatley Church, gypseous rock in the marls crops out at a cattle shed.

At North Wheatley gypsum (locally called "plaster") is quarried in more than one place, one pit is situated in a farmyard below the parsonage gate. The chief pit at the western end of the village exposes a thickness of 20 feet of marls presenting the following section in descending order:—

	Ft.	In.
Red marls - - - - -	5	0
Greenish-grey marl with sandy beds -	6-7	0
Rubbly reddish-brown and bluish-grey marl, consolidated by irregularly intersecting veins of gypsum,— exposed to the bottom of the quarry.		

Gypsum has been obtained from a pit, now overgrown, by the road between North Wheatley and Clayworth, at a copse north-north-east of Hayton Castle. Gypseous marls are exposed in a pit north of the above at a mile and a quarter east of Clayworth Church. Near this, a few chains to the east, hard grey bands, somewhat arenaceous, are exposed; they appear to be dipping a little east of south at about 2°.

Near the letter *r* in the words Fox Cover on the Map, east of the above, marl is exposed in a ditch, two or three red and grey arenaceous bands in it contain pseudomorphs after rock-salt.

By the canal west of Hayton Castle, red marls with an even greenish-grey band are exposed under red clay soil, to a depth of 3 feet, in brick pits.

Grey stony bands occur in the marls between Clayworth Mill and Wheatley Grange. Greenish shaly beds are prevalent in the marls to the east of Wheatley Grange.

In the stream bank where it crosses the canal in the south part of Clayworth, red marl mottled green, with a bed of gypsum 4 inches thick, is shown under alluvial deposits.

In the roadside ditches at and near Beckingham, greenish and grey shaly and stony bands are exposed in places in the marls. Similar bands occur apparently at all horizons in the marl, between the Trent Alluvium, Clayworth, and Misterton;—as between Bole and North Wheatley; on the south-west of Burton Mill, where shaly beds exhibiting ripple-marked surfaces were observed; by the road between Gringley-on-the-Hill and Clayworth, and north of the Field. At a brick pit about half a mile west from Misterton Station, red and green banded marls are exposed, containing a band of thin flaggy sandstones one foot thick with an easterly dip of about 2°.

At Walkeringham Wharf, red marls with greenish bands are in places compacted by irregular veins of gypsum into uneven masses, but on the whole the beds appear to be horizontal. Red and green marls are exposed in numerous brick pits by the Canal west-south-west from Misterton, the most extensive pits being met with in the vicinity of Gringley Wharf. The section at the canal bridge, near the windmill, Misterton, alluded to above, is 8 feet in depth, the alternations being as follows: Red marl, on green shaly bands, on red marl, on green marl, on red and green shaly sandstones, on red marl.

CHAPTER III.*

RHÆTIC (OR PENARTH) BEDS.

Mr. F. M. Burton of Gainsborough first pointed out the existence of the Rhætic Beds in Lincolnshire in a communication to the British Association in 1866. At that time the best section of these beds in Sheet 83 was being exposed in the cutting between the village of Lea and Gainsborough on the Great Northern Railway. Mr. Burton described this cutting in a paper subsequently read before the Geological Society.† He gives the following descending sequence:—

				Ft. In.
Drift	-	-	Fragments of White Lias, &c.	
20. Black fissile shale	-	-	<i>Avicula contorta</i> , <i>Schizodus cloacinus</i>	2 0
19. Dark grey stone with veins of black fibrous gypsum	}		<i>Pecten valoniensis</i> , <i>Avicula contorta</i> ,	0 3
			<i>Schizodus cloacinus</i> , <i>Modiola minima</i>	
18. Black fissile shale, highly fossiliferous, with nests of pyrites, veins of black fibrous gypsum and septaria	}		<i>Avicula contorta</i> , <i>Schizodus cloacinus</i> ,	3 0
			&c.	
17. Dark rubbly sandstone	-	-	-	0 2
16. Black fissile shale	-	-	<i>Avicula contorta</i> , <i>Schizodus cloacinus</i>	1 6
15. Dark highly pyritous sandstone	}		-	0 0½
			-	
14. Black fissile shale	-	-	-	1 0
13. Dark sandstone	-	-	-	0 2
12. Black fissile shale	-	-	<i>Avicula contorta</i> , <i>Schizodus cloacinus</i> ,	1 6
			&c.	
11. Dark sandstone	-	-	-	0 2
10. Black fissile pyritous shale	-	-	<i>Avicula contorta</i> , <i>Schizodus cloacinus</i>	0 4
9. Hard grey laminated micaceous sandstone with pyrites	}		Casts of <i>Avicula contorta</i> , <i>Pullastra arenicola</i> , <i>Perna</i> -?	1 5
			<i>Modiola minima</i> , with teeth, bones, coprolites, ripple-marks, and drift-wood	
8. Black fissile pyritous shale, highly fossiliferous, with septarian nodules	}		<i>Avicula contorta</i> , <i>Schizodus cloacinus</i> ,	2 4
			&c.	
7. Hard fine-grained micaceous and highly pyritous sandstone, the mica in some places in large loose scales	}		<i>Avicula contorta</i> , teeth, scales, and coprolites	0 6
			-	
6. Black fissile shale	-	-	<i>Avicula contorta</i> , &c.	2 0
5. Second Bone-bed, loose in texture	}		Coprolites, &c.	0 0½
			-	
4. Loose grey micaceous sandstone highly fossiliferous	}		Bones, teeth, scales, and coprolites, spines of <i>Hybodus</i> and <i>Nemacanthus</i> , casts of <i>Modiola minima</i> , <i>Pullastra arenicola</i> , &c.	0 4
			-	
			-	-
Carried forward				16 9

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

† *Quart. Journ. Geol. Soc.*, vol. xxiii., p. 315, 1867.

		Brought forward	Ft. in.	
		-	16	9
3. Bone-bed imbedded in a pyritous matrix	{	Coprolites, worn bones, small pebbles, scales, and spines, portion of jaw of <i>Lepidotus</i> (<i>Giebeli</i> ?), teeth of <i>Hybodus minor</i> , <i>H. plicatilis</i> , <i>Sargodon tomicus</i> , <i>Gyrolepis Alberti</i> , <i>Acrodus minimus</i> , <i>Saurichthys apicalis</i> , <i>Trematosaurus Alberti</i> , and <i>Ichthyosaurus</i>	0	1
		-		
2. Black fissile shale with thin veins of grey pyritous stone	{	<i>Avicula contorta</i> , <i>Schizodus cloacinus</i> , coprolites, &c.	8	0
1. Loose grey micaceous sandstone	{	<i>Avicula contorta</i> , portion of jaw of <i>Phiosaurus</i> ? bones, teeth, and coprolites	1	0
			<hr/>	
2 ^a } Blue marl of the Keuper.	{	Total	25	10
1 ^a		-	<hr/>	

"That higher beds of the series," says Mr. Burton (*op. cit.*, p. 320), "existed in those parts is evident from the clean-fractured uneven fragments of White Lias which are found in the overlying drift containing *Myacites musculooides*, *Cardium rhæticum*, and other fossils."

The thirteen years which elapsed between Mr. Burton's examination of the cutting and my visit to it had told their tale, chemical decomposition and surface changes having very nearly obliterated the signs of the bone-beds, which, however, can still be discovered by spudding, and much of the cutting is concealed by grass growth and talus toward Lea Station. The Black Shales rested with every appearance of conformability upon a band of pale green marl 5 feet thick, in all probability discoloured by infiltration through the superincumbent beds.

The greenish marl band crops out on the surface under sand at three-quarters of a mile northward from Lea Station, and its junction with the Black Shales on a level with the rails is 43 chains from Lea Station. For 10 or 12 feet upward from the green marl band, the section consists of black paper shales with dark grey argillaceous shaly limestone bands, apparently impersistent, and micaceous shale with *Pullastra arenicola*. The beds contain much pyrites, and are stained orange and pale chrome yellow near their base. Above these beds a distinguishable band of hard broken pyritous limestone and arenaceous shale with *Pullastra arenicola* crops out on the level of the rails at 33 chains from Lea Station at a bridge over the railway; this is probably represented by beds 7, 8, 9 in Mr. Burton's Section. From the bridge at which this bed makes its appearance to the next bridge over the railway, a distance of 22 chains, the cutting is from 15 to 20 feet in depth; along the lower part Black Shales are exposed; the upper part consists of brown clay with fragments of limestone, *Pecten*, and *Gryphæa*, probably a drift soil under sand.

We have no data for ascertaining whether the Black Shales attain a greater thickness than is assigned to them by Mr. Burton or not, as between the last observation and Lea Station, for 12 chains, the cutting is grass grown, and south of Lea Station nothing but drift-sand is visible for 30 chains; then, at the base of a cutting, there is evidence of Black Shales for about 10 chains; just beyond this, the Rhætic Beds pass under Boulder Clay, which conceals their junction with the Lias. Phosphatic nodules and a

Saurichthys tooth were obtained from the Bone-bed, and *Pullastra* and a fragment of a Gasteropod from sandy shales, in the Lea cutting.

From Lea cutting southward, the Rhætic beds are very meagrely evidenced; they are largely concealed by patches of sand and gravel.

Although they form the surface for some distance north from Gate Burton, the Rhætic shales are not exposed.

Mr. Dalton furnishes the following notes:—

Black shales, with ferruginous weathering along joint and bedding planes, are seen at the platelayers' hut in the railway cutting east of Torksey. The series here is not more than 15 feet thick, between the red Keuper Marls and the Lower Lias limestones.

Southward from Torksey, the Rhætic beds are not exposed in section within the limits of our present district, but are traceable by the ridge produced by their softness and liability to erosion contrasting with the hardness of the limestones in the base of the overlying Lias series, forming together a steep bank of Rhætic shales facing westward, and a gentle slope of Lias descending to the east. This ridge is traversed by the flood channels of the ancient Trent (as shown by the gravels) in six places in Sheet 83, besides others in Sheet 70. A very fine section of the Rhætic Beds is afforded at Beacon Hill, Newark, and is described in the Memoir on Sheet 70, within which it is situated.

W. H. D.

Prof. Hull* assigns a thickness of 66 feet to the Rhætic Beds (?) penetrated in the Scarle (Collingham) boring, the composition as shown by the cores being green siliceous grits. As Mr. Burton only gives about 26 feet for the beds exposed in the Lea cutting, and it is improbable that that estimate would be supplemented by more than 10 feet were the section complete, I am inclined to regard 66 feet as an over-estimate. On the other hand, I consider Mr. Dalton's estimate of 15 feet (*vide* Appendix) may be too small, although I agree with him in taking the first evidence of gypsum in the cores as rather indicative of Rhætic than of Lower Lias beds, and also in including the "green siliceous grits" rather in the Keuper than the Rhætic Beds.

Owing to the extension of the Drifted sands and Boulder clay, the Rhætic Beds occupy a small superficial area north of the Lea cutting. They form a narrow band on the slope below the outcrop of the basement limestones of the Lias from Tyger Holt and Knaith Park to Thurlby Wood, and a much wider tract between Bass Wood and Castle Hill Camp east of Gainsborough; but Rhætic shales are not exposed, the evidence consisting of grey, yellowish, and pale brown surface clays.

Between Castle Hill Camp and Townland Lane House the Rhætic Beds seem to be entirely concealed by drift-soil, from which they emerge on the north, forming the slope below the shelly Lias limestones of Corringham Scroggs, and extending thence by Blyton Station into Sheet 86 on the north. The M.S. and L. Railway-cutting south of the village of Blyton was

* *Proc. Inst. Civ. Eng.*, vol. 49, p. 162.

made in 1848, but no one appears to have made a note of its geology whilst the details were clearly exposed.

By the road from Blyton Station to Blyton the Black Shales of the Rhætic were noticed in a stream bank; the exposures from the turning to the Station northward are for the most part in Sheet 83. Opposite the turning to the Station the lower part of the stream bank exposed beds very much resembling shaly Keuper marls, greenish and reddish, but the appearance was found to be due to a slimy surface coating and ferruginous matter; the laminæ showed undulations; but on the whole the beds are horizontal. A few chains further north, Black Shales were exposed containing a thin layer of selenite. Black Shales were evidenced for from 3 to 9 chains from the turning to the Station, and at about 13 chains from it they were again visible under Boulder Clay soil, sand, and alluvial matter, and also at about 5 chains further north. The stream would appear to coincide with the strike of the beds, the land rising westward in a dip-slope rendered irregular by surface deposits; whilst on the east of the road, Boulder Clay and sand precludes any further observation of the Rhætic Beds, and entirely conceals their junction with the Lias.

CHAPTER IV.*

LOWER LIAS.

The Lower Lias beds occupy a considerable area in Sheet 83, but a glance at the Map will show to how large an extent they are concealed by surface deposits. In the southern part of the area under description, the surface is frequently masked by extensive tracts of gravel and sand, beneath which the Lower Lias beds are occasionally visible in gravel pits and other excavations.

To the north of Broxholme, Willingham, and Marton, Chalky Boulder Clay covers so considerable an area that the composition of the Lower Lias can only be partially inferred. The upper beds are barely evidenced in valleys at the north margin of the Map, and the middle are entirely concealed, but the lower beds afford much greater facilities for observation.

Mr. Dalton considers that the Lower Lias is susceptible of division into the following three members in the southern part of the area, viz. :—

- c. Clays with a sand belt (apparently representing the zone of *Ammonites armatus*), including the zones of *A. capricornus*, *A. Jamesoni*, *A. armatus*, and *A. oxynotus*.
- b. Ferruginous sandstone with subordinate clays, the zone of *Ammonites semicostatus*.
- a. Clays with limestone bands in the upper and lower parts, zones of *Ammonites Bucklandi*, *A. angulatus*, and *A. planorbis*.

The termination of the main mass of Boulder Clay a little north of Willingham allows the Liassic features to be observed, as the sandy Drift-patches about Stow and Willingham are neither thick nor extensive. Proceeding eastward from Marton Station we encounter depressed escarpment features facing west, with gentle dip-slopes, marking the successive outcrops of the harder limestone beds in the shales and clays of the Lower Lias.

If we could regard these features as indicative of the positions of the Ammonite zones, we should have the *A. planorbis* zone succeeded by the zone of *A. angulatus* between Kexby and Stow Park, succeeded by the *A. Bucklandi* zone between Axham Wood and Willingham. But, as both the *A. angulatus* and *A. Bucklandi* beds are intercalated clays and limestones, and in the Lower Lias the persistence of definite lithological characters, such as the relative proportion of clays to limestones in any set of beds, can by no means be reckoned upon, I have found it impossible to draw lines for the Ammonite zones on the south of the Boulder Clay area. Had the attempt been made it would have been impossible to have traced them northward.

The lower beds of the Lower Lias are more continuously evidenced from Marton Station northward than the overlying beds,

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

owing to the larger valleys cut through the Boulder Clay between Pilham and Upton. Beds probably representing the zones of *A. angulatus*, *Bucklandi*, and *semicostatus* are at the surface from Stow Park and Sturton to Kexby Green, Willingham, and Heap-ham Brick-yard, and may also occur in the valley between Aisby and Yawthorpe, and in its tributary valley near Dunstall Farm. The upper beds of the Lower Lias are concealed by Boulder Clay north of a line between Ingham and Willingham Gorse, only occurring on the surface by the sides of the stream valley near Huckerby and Willoughton Grange, and in the next valley on the east just near the north margin of Sheet 83.

The lowest beds, which consist of shaly limestone associated with clay, much resembling the basement beds of the Lias at Elton Station in the Newark district, and above them shelly limestones and dark grey limestones in shales and clays, apparently constitute the *A. planorbis* zone.

The *A. semicostatus* zone probably lies between Dunstall Farm and Huckerby Farm, and runs in all probability southward by way of Yawthorpe and Yawthorpe Gorse, Harpswell Wood and Glentworth Gorse, whence it may run between Willingham and Willingham Gorse, and by Stow to Sturton; so that we may say that the upper boundary of the Lower Lias appears to be within a mile west from the villages of Blyborough, Willoughton, Hemswell, Harpswell, Glentworth, and perhaps Fillingham.

(a) *Clays and Limestones.*

The following notes are by Mr. Dalton:—

Half a mile east-south-east of Collingham Station is a small quarry and lime-kiln in the *A. planorbis* beds. Some of the slabs are crowded with *Avicula* and other shells.

In the blue clays near the base of the *A. Bucklandi* zone west of Warren House, and at a somewhat higher horizon three-quarters of a mile northwards of Norton Disney, the thin limestones of this zone are seen in ditch sections. The same limestones richly fossiliferous, are raised in draining west of Eagle, and further down, the clays without limestone bands (zone of *A. angulatus*) were seen along the road.

The following is a list of fossils obtained from the Lime Kiln pits, half a mile east-south-east of Collingham Station:—

Avicula inæquivalvis, Sow.
Lima gigantea, Sow.
Modiola minima? Sow.
Monotis papyria, Quenst.
Ostrea liassica, Strick.
Pleuromya.
Ammonites planorbis, Sow.
 Bone fragment.

There is an old quarry near the south end of Wigsley Wood, and fragments of the *A. planorbis* limestones thickly strew the fields here and on the low ridges near Thorney and Kettlethorpe. The rock is seen in the railway cutting east of Torksey, and has been quarried near here to the extent of some 3,000 or 4,000 tons for local building purposes. It is also exposed on the hillside above Brampton Grange.

In a quarry half a mile south-west of Wigsley *Modiola minima*? Sow., and *Pleuromya crowcombeia*? Moore, were found by Mr. Rhodes in "limestone at the base of the Lower Lias. The quarry has been filled in."

Mr. Rhodes found the following in a ditch exposing "blue limestones weathering yellow," probably belonging to the zone of *A. Bucklandi*, at half a mile north of Eagle Church.

Crinoid.
Gryphæa arcuata, Lam. (*incurva*, Sow.)
Lima gigantea, Sow.
Ostrea liassica, Strick.
Astarte.
Cardinia Listeri, Stutch.
Lucina.
Unicardium cardioides, Phil.
Cryptæna.
Eucyclus.
Ammonites.

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Lower Beds (probably constituting zone of A. planorbis).

The lowest beds of the Lias are exposed in the road near Burton Mill, and consist of shaly limestones associated with light brown clay and a bed of nodular broken limestone, in all 10 feet or more in thickness: *Pullastra* was obtained.

At the bend in the by-road near Gate Burton Church, thin shaly (ripple-marked and rain-pitted in places) limestones (? with worm-burrows) are associated with light brown shale. Similar limestones, clays, and shales are evidenced in old pits on the hillside at the west margin of High and Low Fox Cover, near Knaith Wood House.

By the road from Marton to Marton Station yellowish brown clay with thin beds of shaly limestone containing fossils is exposed in a ditch. The ground forms the dip-slope of these beds for some distance from the crest of the hill above Marton toward the Station.

At the letter G. of the words Gowdale Nook on the Map, a pond marks an old quarry from which bluish grey shales with crushed *Mytili*, &c., and fragments of hard dark blue earthy limestone with numerous *Ostreae* and containing *Ammonites planorbis* have been turned out.

On the east side of Burton Wood light brown shelly limestone is evidenced.

In the Railway Cutting near Gowdale Nook dark grey fossiliferous shales, and grey and brownish shales, coarsely laminated in places, are exposed.

In the cutting near Long Nursery dark grey shales are evidenced. Both cuttings are capped by Boulder Clay.

In shallow brick pits, between Kexby Green and Knaith Wood House, dark grey Lias shales are exposed under light brown and grey clay with a nodular bed of earthy limestone containing *Pentacrinus*, &c.

The soil in the valley between Upton and Knaith Wood House is blackish clay; on the east side of Thurlby Wood brownish shelly limestones, crowded with *Ostreae*, are evidenced. About Riding Wood and Whites Wood, fragments of shelly limestone occur on the surface.

In the Somerby Hall valley, north-west of the house, dark grey shales were turned out from a well.

Lias forms the surface from the Somerby Hall valley by Corringham Leas to Springthorpe and near Heapham Mill, but although beds higher than the *A. planorbis* zone occur, no more definite evidence than clay soil is obtainable. Whether the Willingham Lias is continuous through the valleys between Upton and Heapham with that of Springthorpe valley, is doubtful.

The general succession of the beds along a line drawn through the words *Corringham Scroggs* on the Map would appear to be in the following ascending order from the Black Shales of the Rhætic Beds:—

Irregular shaly light brown shelly limestone in light brown clay, probably decomposed shales.

Dark grey shales, weathering brown and grey, with occasional beds of dark grey earthy limestone with *Gryphæa incurva*.

Beds of shelly limestone seem to have been got out from pits (filled with water on the occasion of my visit) at the Farm north of the letters *Ser* of the word *Scroggs* on the Map.

By the drain, one mile due west of the principal Inn in Little Corringham, Lias shales are well exposed under a thin Boulder Clay soil.

Near Townland Lane House, on the east, Lias shales have been got out; the pits afford no section, and the materials excavated are mixed with Boulder Clay débris. At about 12 chains north-north-east from Townland Lane House, by the path shown on the map, Lias shales are evidenced at about 3 feet from the surface.

Mr. Cressey, Well-sinker, Scunthorpe, informed me that the well at a New Farm house in Pilham, about 300 yards from Blyton Station, was sunk through:—

			Ft.	In.
Clay -	-	-	-	12 0
Pieces of stone, large († impersistent or broken beds)	-	-	-	6 0
Dark clay	-	-	-	6 0
Red clay	-	-	-	6 0
Blue bind—shale—in which the sinking was abandoned.				

The above must be in the Lower Lias, but as the information was communicated verbally, it not being the practice to keep records of well sections in this country, it cannot be said to throw much light on the relations of the beds.

Beds above the A. planorbis zone.

Thirty chains west from Stow Church beds of bluish grey limestone containing numerous fossils, amongst which *Lima gigantea* abounds, are exposed in association with light brown clay in the road; a new species of *Lucina* was also obtained.

At Sandy Bush shelly limestones, containing *Pentacrinites*, are associated with brownish, probably weathered, shales, containing *Gryphæa incurva*; the same beds are evidenced between Sandy Bush and Axham Wood. The beds mentioned in the two preceding observations are similar to those ascribed by Mr. Burton to the *A. angulatus* zone from the discovery of that fossil in them.

The *A. angulatus* beds may be succeeded by those of the *A. Bucklandi* zone, either at Axham Wood or Sturton Mill.

Mr. Burton discovered *Ammonites Bucklandi* in the beds exposed in the railway cuttings in the vicinity of the second bridge over the railway south of Marton Station.

By the road to Lea Station at about a mile east of Kexby, dark grey clay with *Gryphæa* is evidenced.

At the brickyard, shown on the Map, south of Heapham, dark grey shales and limestones, crowded with *Gryphæa*, have been turned out from beneath about 5 feet of sandy loam.

North-east of Great Corringham, at the letters *iel* in the words *Aisby Field* on the Map, a quarry shows grey limestones with *Gryphæa incurva*, interbedded with, and impersistent in, grey shales under from 2 to 3 feet of Boulder Clay and sand.

Lias is evidenced near the surface on the west of Dunstall Farm in the main valley, but in the tributary valley south-east of the Farm dark grey shales and grey earthy limestones, with numerous *Gryphæa*, have been got out; the refuse is indistinguishable from the beds of the *A. planorbis* zone at Gowdale Nook, but it belongs to the same series as the Heapham Brickyard and Sturton beds.

(b.) Ferruginous sandstones.

The following note is by Mr. W. H. Dalton:—

These beds were seen in the Witham half a mile north of Bassingham, and were at one time worked for road-metal about Haddington and Thorpe-on-the-Hill, whence they give rise to two rather prominent undulations of the surface.

Except in ditch-sections, no exposure of these beds occurs at the present time. Beds of stone, probably belonging to this series, have been detected in Ingoldby Wood and on the road from Saxelby to Broxholme. A fairly-marked feature, presumably denoting the base of the series, extends from Saxelby to Sturton Mill.

In the Witham at a mile north from Bassingham Church, the following fossils were obtained :—

Rhynchonella.
Spiriferina Walcottii, fragment, Sow.
Gryphæa arcuata, Lam. = *G. incurva*, Sow.
Lama.
Ostrea.
Pecten Thiollieri, Martin, fragment.
Pinna.
Pholadomya ambigua, Sow.
Unicardium cardioides, Phil.
Chemnitzia liassica, Quenst.
Eucyclus gaudryanus, D'Orb.

In a ditch section one mile north-west of Aubourn Church, Mr. Rhodes obtained *Pecten*, *Nucula*? and *Pholadomya ambigua*? Sow.

In the same set of beds exposed in a ditch one mile south of Thorpe-on-the-Hill Church and by the side of the road opposite New House, Mr. Rhodes found *Ostrea liassica*, Strick., and *Pecten*.

The *A. semicostatus* zone, which is so well represented by the Frodingham ironstone in North Lincolnshire, may possibly be represented at Sturton and Stow, where ferruginous beds occur, as Mr. Dalton believes the beds cropping out in the neighbourhood of Coates, Thorpe in the Fallows, and Broxholme to be higher in the series. Near Sturton, on the west, a pit has been excavated in bluish clay, with grey fossiliferous, ferruginous limestone.

At nearly a quarter of a mile south from Sturton, a well was being sunk through 5 feet of grey and brownish clay with selenite, upon bluish-grey clay with bluish-grey limestone, containing numerous *Gryphæa*, apparently broken and impersistent. Toward the surface the clay is mixed with Drift sand and loam, probably washed down through cracks. At about three-quarters of a mile east of Sturton, dark bluish-grey Lias clay is exposed in brick pits under 4 feet of soil. The local name for the Lias clay in the pits is "*Dyas*."

Under the westernmost (outhouse) Farmhouse, in the village of Stow, decomposed ferruginous rubbly limestone, crowded with *Gryphæa* and *Cardinia*, is exposed *in situ*. The fossils are easily disengaged from their disintegrated matrix. *Cardinia Listeri* was obtained. On the east side of Stow Church a depression in a farmyard showed rather thick beds of bluish-grey earthy limestone, with numerous *Gryphæa*, to judge from surface blocks. South of Willingham and west of Normanby, from some old pits now grown over, grey limestones, crowded with *Gryphæa*, have been got out. At Normanby, by the turning to the west, toward the River Till, a bed of grey limestone, crowded with *Gryphæa*, is shown *in situ* on the margin of a pond in a farm-yard. A similar bed has been got out from a pond rather more than a quarter of a mile south from Willingham Church, and possibly also at the bend in the road on the opposite side of the River Till, north-east of Normanby.

On the east of the River Till, north-north-east of Normanby, and east-south-east of Willingham, rubbly brown limestones occur *in situ* in ditches in a brown loamy clay, containing numerous *Gryphæa* and fragments of other shells, *Ostrea*, *Pecten*, *Arca*, *Cardium* were obtained. These beds are in all probability representative of the *A. semicostatus* zone, which becomes loamy in the southern part of Sheet 86.

By the River Eau, north of Dunstall Farm, near the southern margin of Sheet 86, *Ammonites semicostatus* has been found in ferruginous beds.

On the east side of the valley north of Dunstall Farm, at a quarter of a mile within the northern margin of Sheet 83, indications of ferruginous rock were met with in a ditch.

c. *Clays.*

Mr. Dalton furnishes the following note :—

Bassingham brickyard, nearly a mile and a half east-south-east of the village, shows a very fossiliferous belt of sand and sandy limestone, interbedded in clays of the ordinary type. The section here was as follows in 1883 :—

	Ft.	In.
Sandy and pebbly clay, relics of Drift mixed with weathered Lias	-	1 6
Unmixed Lias clay	-	1 6
Ferruginous sandstone	-	2 0
Calcareous rock, many fossils	-	2 0
Blue clay of normal Lias type	-	6 0

The fossils show relations with both the zones of similar lithological character, that of *A. semicostatus* below and the Marlstone above. These beds probably represent the zone of *A. armatus* (see the account of their southward extension in the memoir on Sheet 70), and appear to range northward by Broxholme to Coates, where they are lost under the Boulder Clay. Their course north of the Till is marked by a bold rise, probably due to hard beds, but there are no good exposures. Ironstone was seen in a pond about 200 yards east of Broxholme Church, and there is a brickyard at Till Bridge, though rather lower in the series than that of Bassingham, and showing only unfossiliferous layers, as does an old brickyard at Coates.

W. H. D.

The following is a list of the fossils obtained by Mr. Rhodes from the ferruginous sandy limestone exposed in the Bassingham brickyard :—

Pentacrinus, stem.
Avicula inæquivalvis, Sow.
Gryphæa cymbium, Lam. = *Maccullochii*, Sow.
Pecten liasinus, Nyst.
Pinna Hartmanni, Ziet.
Cardinia Listeri, Stutch.
Modiola scalprum, Sow.
Pholadomya ambigua, Sow.
Pleuromya unioides? Röm.
Ammonites subplanicosta, Oppel.

At Aubourn, seven miles south-south-west of Lincoln, a doubtful specimen of *Pholadomya ambigua* was obtained.

South of Lincoln, the upper beds of the Lower Lias, according to Professor Judd's system, embrace the range of *A. capricornus* as far as ascertainable, and where, as appears to be almost invariably the case, that fossil is subordinate to *A. margaritatus*. South of Waddington Station the boundary between Middle and Lower Lias is very indefinite; the ground, which slopes gently to the east, is partially covered by Drift sand and gravelly loam; the grey clays exposed in some of the ditches furnishing no criterion of its position, the line has been drawn partly by feature and always as far as possible on the horizon taken on the north border of Sheet 70 by Mr. Holloway, than which I do not see how a better could have been selected; and in accordance with the exposure of *A. capricornus* clays in the Waddington Station Pit, and the general contour.

Mr. Dalton observes :—The first pit worthy of note is that of the Lincoln Brick Co., north of Waddington Station. Here is seen some 15 feet of blue thick bedded clay, with septarian nodules crowded with fossils, of which *A. capricornus* is one of the most abundant. The septa of these nodules sometimes consist of fine asbestiform carbonate of lime, resembling spun glass in texture.

W. H. D.

This pit, when visited in April 1885, showed about 30 feet of clay; the following observations were made:—For 6 feet from the surface the clay weathers to a lighter grey tint, below this it consists for the most part of dark grey clunchy clay, containing red ferruginous septaria, and cement stones in the upper part, and grey nodules below; *Ammonites capricornus* seems to occur in all the nodular bands to within 8 feet from the surface. It is very plentiful in the ferruginous and concretionary nodules forming the extensive spoil heaps in the pit; from the same source *Ammonites striatus* and large oysters were also obtained. The uppermost 6 feet in this pit are included in the Middle Lias.

The following is a list of the fossils obtained from this pit:—

Wood.	<i>Modiola scalprum</i> , Sow.
<i>Rhynchonella variabilis</i> , Schl.	<i>Pleuromya unioides</i> , Röm.
<i>Gervillia levis</i> , Buckm.	<i>Pholadomya ambigua</i> , Sow.
<i>Leda galathea</i> ? D'Orb.	<i>Unicardium</i> .
<i>Ostrea</i> .	<i>Actæonina</i> .
<i>Pecten æquivalvis</i> , Sow.	<i>Eucyclus imbricatus</i> , Sow.
„ <i>Thiollieri</i> ? Martin.	<i>Ammonites capricornus</i> , Schloth.
<i>Plicatula spinosa</i> , Sow.	„ <i>subplanicosta</i> , Oppel.
<i>Cardium truncatum</i> , Sow.	„ <i>striatus</i> , Rein.
<i>Goniomya</i> .	<i>Belemnites clavatus</i> , Schloth.

The Bracebridge Brick Company's pit is a mile and a quarter north of Waddington Station pit. The section is for the most part included in the Middle Lias, but in the south side of the pit, from 5 to 10 feet upward from the floor, the clay is dark grey and clunchy, containing cement-stone nodules often round and nearly symmetrical, in which *A. capricornus* occurs in abundance, and *A. striatus* more sparingly. These beds are included in the Lower Lias, and that formation forms an inlier in the floor of the pit, but *A. margaritatus* was obtained at 3 feet above the floor, *vide* p. 27, in another part of the pit.

Between the Bracebridge pit and Lincoln Racecourse the uppermost beds of the Lower Lias seem to be entirely concealed by Alluvium and sand and gravel. From Lincoln to North Carlton, the boundary between Middle and Lower Lias is very indefinite; the land slopes gently westward, and is more or less covered with sandy soil. Clunchy grey clay is turned up in drains between Bishop's Bridge and Burton and to the east of Burton. From North Carlton to Fillingham, owing to the prevalence of Boulder Clay, the boundary line is still more indefinite.

Mr. Dalton adds the following note:—From South Carlton to Ingham, the only sections in the Lower Lias are those casually laid open in the clearing of drains and ponds.

Beds above the A. semicostatus zone.

In a ditch by a new road, at about three-quarters of a mile west of Glentworth Church, dark grey Lias shales with selenite crystals, and traversed by yellow bands, as if resulting from decomposition of pyrites, are exposed under Boulder Clay, at about 6 feet from the surface. These beds have rather the aspect of Lower than Middle Lias; if so, they are very high in that series. From Willoughton Grange to Ingham, Boulder Clay, on hill tops and in valleys alike, conceals the Lower Lias clays.

In the valley north of Willoughton Grange, blue Lias clay is exposed under the Alluvium by the stream and in drains on the slope, under Boulder Clay soil, where they are deep enough to show it. In the next valley, at the north margin of Sheet 83 (W. Long. 0° 37') there are signs of Lias clay under the Alluvium, and, on the east side of the valley, obscure signs of the Pecten Bed ironstone, which has, in Sheet 86, been taken as the base of the Middle Lias. These signs are reliable, being in line of strike with more certain evidence not far off in the adjacent Sheet 86.

CHAPTER V.*

MIDDLE LIAS.

The Middle Lias consists of two members, viz. :—

An upper series of ferruginous limestones called the Marlstone Rock-bed.

A lower series of shales and clays more ferruginous and arenaceous in the upper part.

In Sheet 83 the boundary between the Lower and Middle Lias is rendered peculiarly indefinite by the great spread of Boulder Clay and sand at the foot of the Oolitic escarpment, north of Lincoln. The difference in the character of the Junction beds in Sheet 86 on the north, and in Sheet 70 on the south, tends to increase this uncertainty.

In Sheet 70, as in Rutland, the junction has been inferentially taken as far as possible at the boundary between the zones of *Ammonites capricornus* and *A. margaritatus*, which are lithologically indistinguishable.

In Sheet 86, on the contrary, *A. margaritatus* has not been found, and *A. capricornus* makes its appearance at a few feet below the Rock-bed, and ranges downward to a ferruginous stratum about 60 feet below the Rock-bed, characterised by *A. striatus* and an abundance of Pectens, and called the Pecten Bed. *A. capricornus* occurs for some feet below the Pecten Bed, which has in Sheet 86 been taken as the base of the Middle Lias, being the first lithological horizon in the clays beneath the Marlstone Rock-bed.

In the south part of Sheet 83 the evidence of the position of the boundary is derived from several pits in the neighbourhood of Lincoln, where *A. capricornus* and *A. margaritatus* have been found. In one of the most important of these, the Bracebridge Brick Co.'s Pit, the lowest beds are characterised by the occurrence of numerous specimens of *A. capricornus*, and less frequently, of *A. striatus*.

Prof. Judd (Geology of Rutland, p. 74) records the occurrence of *A. capricornus* in the Middle Lias Clays in one place. *A. margaritatus* has never been included in the Lower Lias, whereas *A. capricornus* occurs in the basement beds of the Middle Lias of Yorkshire. So that, should there be occasional evidences of a blending of these two forms, the presence of *A. margaritatus* is much more conclusive than that of the commoner form, which, though locally zonal, often has an irregular and capricious range.

From Navenby to North Carlton the boundary has been drawn in accordance with feature from Mr. Holloway's line in Sheet 70 northward, and with reference to the evidence obtained from the railway cutting near Coleby, the Waddington and Bracebridge Brick-pits, and the pits near Lincoln Racecourse.

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

From North Carlton northward the boundary is rendered still more indefinite by a sheet of Chalky Boulder Clay.

Pursuing the classification adopted in Sheet 86, the boundary of the Lower and Middle Lias has been taken as far below the Rock-bed as we conjecture the horizon of the Pecten Bed to be, tracing it southward from some indications of the bed on the north margin of Sheet 83 (W. long. $0^{\circ} 36' 55''$), and near Willoughton Grange.

From its indefinite character the boundary between Middle and Lower Lias is shown on the map by a broken line.

In the southern part of Sheet 83 the Marlstone Rock-bed is absent; it is last seen at the village of Burton, and does not reappear for 12 miles, between that place and the village of Wellbourn, 2 miles south of the northern margin of Sheet 70.

Near Wellingore in the northernmost part of Sheet 70 (*vide* Memoir on that Sheet) there is every reason to conclude that the Rock-bed is represented by from 12 to 15 feet of shales based on a hard bed with phosphatic nodules which contains numerous specimens of *A. communis* and is in all probability equivalent to, or on the same horizon with, the actual base of the Rock-bed.

A. communis has been obtained from the Rock-bed north of Ingham; but south of Burton it has not been noticed in the ferruginous nodular bands which occur in the upper clays of the Middle Lias.

South of Burton the most marked horizon in the Middle Lias is a ferruginous nodular bed with phosphatic concretions, which is shown at about 20 feet below the base of the Upper Lias in the Bracebridge Brick Co.'s pit near Lincoln, and is so similar to a band occupying an analogous position below the Marlstone Rock-bed at Gonerby, near Grantham, that Mr. Dalton was led to infer their identity. The persistence of the bed in the intermediate districts has not been proved, and it is evidently lower in the series than the bed at Wellingore.

Mr. Dalton gives the following general description of the occurrence of this bed near Lincoln:—

The lower member of the Middle Lias, otherwise called the zone of *A. margaritatus*, is composed of rather thinly laminated ferruginous shale, with bands of septaria and continuous seams of a stone containing almost enough oxide of iron to be termed ironstone, and which we may call iron-rock. This substance forms a bed three or four feet thick, portions of its base being crowded with phosphatic pebbles. The subjacent clays pass up by rapid alternations of thin iron-rock and shale of increasingly ferruginous character into the solid band.

W. H. D.

Both at Lincoln and Grantham, whilst specimens of *A. margaritatus* have been obtained beneath this ferruginous nodular band, no signs of that fossil were observed above it, so it seems to form the local upward limit of the zone or range of *A. margaritatus*.

This circumstance, coupled with the prevalence of ferruginous nodules and, as a general rule, more arenaceous materials in the upper part of the Middle Lias clays, suggests a probability that the absence of the Marlstone Rock-bed may be due to its abnormal representation by about 20 feet of clay down to the ferruginous nodular band. But, if this is the case, and the Grantham bed on the horizon of that at Lincoln, we must also include in the Rock-bed series more than 20 feet of clay below the Rock-bed where it is not only present but well developed.*

In the commencement of the following passage, Mr. Dalton seems to have admitted the possibility of the representation of the Rock-bed by clays in the districts where it is absent:—

The Marlstone Rock-bed forming the zone of *A. spinatus* appears to be unrepresented, unless by clays inseparable from those below it, from Navenby to near Burton. Here it reappears, and, though thin, is continuous northward to the edge of the sheet. It has its usual character of a hard, somewhat ferruginous sandy limestone, sometimes crowded with fossils, sometimes with phosphatic pebbles and small water-worn slabs with indistinct casts of shells. The iron is sometimes in concretionary masses, but more generally diffused uniformly through the rock.

W. H. D.

From Fillingham northward, the junction of the Upper and Middle Lias is for the most part distinguishable by feature. The Rock-bed cropping out at the base of the Upper Lias slopes is exposed in section and evidenced by feature and surface soil between Fillingham and Glentworth, between Harpswell and Hemswell, and between Willoughton and the northern margin of Sheet 83.

Between Glentworth and Harpswell the relations of the Upper and Middle Lias are rendered obscure by the presence of superficial deposits.

Between Hemswell and Willoughton also, the geology is very obscure, and the position and extent of the Rock-bed very questionable.

MIDDLE LIAS CLAY.

A cutting north of Navenby now grassed over only affords evidence of grey shaly clay in the drain at the base of the cutting. The cutting is about a quarter of a mile in length, thin brown ferruginous stone in grey shaly clay seems to have been got out at the signal-hut.

Mr. Penning furnishes the following note on this locality:—

A thin bed of nodular iron-rock is exposed in the railway cutting three-quarters of a mile north of Navenby Station. In the railway cutting west of Boothby Graffo a few inches of brown iron-rock is exposed at the level of the rails, with blue clay above and below it. Similar beds are seen below Coleby.

W. H. P.

In ferruginous clay at a pond below Coleby *Chemnitzia* was obtained.

The railway cutting west of the south end of Coleby village is 15 or 16 feet in the highest part. At its base a hard bed of impure micaceous limestone and

* Professor Judd (Geology of Rutland, p. 75), describes a case similar to this.

cement nodules, containing *Goniomya v-scripta* and numerous gasteropods, is exposed; above this, the cutting is grassed over. The following fossils were obtained from the hard bed by Mr. J. Rhodes, the Survey fossil collector:—

Pecten liasinus, Nyst.
Cardium truncatum, Sow.
Cardita multicostata, Phil.
Goniomya hybrida, Münst.
Eucyclus imbricatus, Sow.
Turbo cyclostoma, Benz.
Ammonites margaritatus, Montf.
Belemnites.

Mr. Penning furnishes the following note:—

In the old brickyard half a mile west of the south end of Waddington village, the beds consisted of—

Grey marly clay	-	2 ft.
Iron-rock	- - -	1½ to 2 feet.
Bluish-grey shaly clay		over 10 feet.

The sand which covers the surface to a varying depth is washed down from the Northampton Sands on the escarpment above, and caught on the shelf of Middle Lias.

W. H. P.

This pit now exposes about 15 feet of grey shaly micaceous clay, with one or two bands of cement-stones, the largest being about 10 feet from the surface.

Mr. H. B. Woodward obtained *Goniomya v-scripta* in a bed similar to that exposed at the base of the cutting west of Coleby, and occurring here at 4 or 5 feet from the surface. Mr. Woodward also obtained fragments of *Ammonites margaritatus* in the debris, showing the characteristic corded keel. The deepest sinking in the floor of the pit was full of water on the occasion of our visit (April 1885). We obtained *Pecten æquivalvis*, Sow., in nodules in the clay in this pit.

The following is from Mr. Dalton's notes:—

Somewhat more than a mile to the north of Waddington Station is the pit of the Bracebridge Brick Co., extending from high in the Middle Lias downward, and probably reaching the upper beds of the Waddington Station pit. As in the latter, the clays and their septaria are highly fossiliferous.

The Bracebridge Brick Co.'s pit has yielded the following measurements at different points:—

1.—*W. H. Penning.*

2.—*W. H. Dalton.*

	Ft.	In.		Ft.	In.
Clays	-	5 0	Grey clays	-	17 0
Interrupted iron-rock	-	0 6	Nodular iron-rock	-	0 3
Grey marly clay		0 6	Shale with phosphatic pebbles		0 8
Iron-rock with phosphatic nodules and iron pyrites			Iron-rock		2 4
and a thin clay bed at the base	-	3 0	Sandy shale		0 6
Grey shaly micaceous clay			Iron-rock	-	0 3
				-	47 0

The heaps of septaria which are left on the floor of the pit between periodical removals may be distinguished by their colour, the yellowish grey from the lower beds being very distinct from the crimson and tawny masses from the shales above. Amongst the latter are some highly fossiliferous slabs, and also masses of conglomerate of phosphate pebbles in a matrix of iron-rock.

W. H. D.

Since the above observations were made, the workings in the central face and southern side of the Bracebridge pit have been still further extended. Owing to the easterly dip of the beds, the highest beds are exposed in the central face of the pit, and are inaccessible for some feet from the surface,

whilst the lowest are shown in a sinking in the floor of the pit on the west side and in its south-west face. The following observations were made in April 1885 :—

Section on the north side of the Bracebridge pit.

		Ft.	In.
	Grey shale -	4	0
	Ferruginous cement stone -	0	6
	Grey shale -	3	0
Nodule bed {	Sandy ferruginous clay and nodular stone, with phosphatic concretions -	1	0
	Ferruginous nodular cement-stones stained crimson on exterior, and mixed with arenaceous shale -	3	0
	Grev micaceous shaly clay, often stained pale chrome, with bands of nodules, concealed by talus at base	about 25	0

In the centre face of the pit nodular stone with phosphatic concretions and *Beleninites* occurs at the base of the nodule-bed. The uppermost bed in this place, where Mr. Dalton's section was probably taken, is now shown to be very ferruginous, suggesting a representative of, or approach to, Marlstone. Below the nodule-bed, about 30 feet of dark grey clunchy clay, splitting in thick shaly pieces, and containing nodules, was shown down to the floor of the pit in the central face. This clay contains many small *Ammonites*, too fragile for preservation; *Goniomya v-scripta* was obtained from it at about 5 feet above the floor of the pit.

In the south-west side of the pit dark grey clunchy clays, with round nodules containing many specimens of *Ammonites capricornus*, and less frequently, *A. striatus*, form the base of the section for about 10 feet upward from the floor. These clays are probably below the site at which Messrs. Rhodes and Macconochie obtained *Ammonites margaritatus* in another and more central part of the pit, and are taken for 8 to 10 feet upward from the quarry floor, where the lowest beds are exposed, as Lower Lias (*vide* Notes on Lower Lias, p. 22). But as the range of *A. capricornus* is irregular, it is possible that that Ammonite might occur in abundance here in the basement beds of the Middle Lias, on a horizon on which it has been exceptionally found in Rutland.

The clays here are used for the manufacture of bricks, drain-pipes, &c.

The following is a list of the fossils obtained from the Bracebridge Brick Company's pit, or Clark's pit, 2½ miles S.W. of Lincoln Cathedral, under the Nodule bed, by Messrs. Rhodes and Macconochie :—

- Wood.
- Crinoid ossicle.
- Rhynchonella*.
- Waldheimia perforata*, Piette.
- Lima gigantea*, Sow.
- L. pectinoides*, Sow.
- Ostrea irregularis*, Münster.
- Pecten aquivalvis*? Sow.
- * *P. lissinus*, Nyst.
- Cardium truncatum*, Sow.
- Goniomya hybrida*? Münster.
- † *Gresslya donaciformis*, Phil.
- † *G. intermedia*, Simps.
- † *G. Seebachii*, Brauns.
- Hippopodium ponderosum*, Sow.
- Leda*, n. sp.
- L. graphica*, Tate.
- * *L. imbricata*, S. and N.

* Obtained in clay with septaria directly below the nodule-bed by Mr. Rhodes on a subsequent visit.

† Obtained in clay near base of workings by Mr. Rhodes on a subsequent visit.

Modiola scalprum, Sow.
Pholadomya.
Pleuromya unioides, Röm.
Unicardium cardioides? Phil.
Eucyclus imbricatus, Sow.
Ammonites capricornus, Schloth.*
†*A. nitescens*, Y. & B.
†*A. margaritatus*, Montf.†
A. striatus, Rein.*
Belemnites clavatus, Schloth.
Bone, fragment.

From the nodule bed in Bracebridge Brick Company's pit, Mr. Rhodes obtained the following: (a) denotes that the specimens to which it is prefixed were obtained in the nodules forming the upper part of the bed, and (b) distinguishes those from the ferruginous part of the stratum beneath:—

Waldheimia perforata, Piette.
a *Avicula cygnipes*, Phil.
a *Ceromya liassica*, Moore.
a b *Gresslya donaciformis*, Phil.
Plicatula spinosa, Sow.
Pleuromya unioides, Röm.
b *Unicardium cardioides*, Phil.
Eucyclus imbricatus, Sow.
Turbo.
b *Ammonites margaritatus*, Montf., Young.
a *Belemnites vulgaris*, Y. & B.

At the further end of the village of Bracebridge is the deserted brickpit formerly worked by Messrs. Kirk and Parry. Here also the Middle Lias has from time to time yielded a somewhat varying section. Mr. Penning records the following particulars:—

At the north end of the pit—

	Ft.
Sand with ironstone concretions on an irregular surface of the clay below - - - - -	3
Blue, very compact, shaly clay, with a three-inch band of non-calcareous flattened nodules and a thicker band of septaria about 10 feet below, some calcareous, others not so. There are a good many phosphatic concretions in the clay, and some of the septaria exhibit a slickensided structure - - -	18

At the south-east corner of the pit—

	Ft.	Ins.
Sand with a clayey base, full of hard flat lumps of calcareous grit - - - - -	2 ft. to	3 0
Blue clay - - - - -	-	3 0
Band of iron-rock - - - - -	3 in. to	0 6
Blue clay - - - - -	-	2 6
Band of iron-rock - - - - -	3 in. to	0 6
Blue clay - - - - -	-	2 0
Yellowish-brown iron-rock, some of the concretions hard, others soft and ochreous - - - - -	-	2 0
The last bed throws out a spring; it is 43 feet above sea level and dips at 3° to E. by N.		

W. H. P.

The iron-rock at the base should be 2 feet 8 inches thick, and the succeeding clay bands 1 foot 10 inches and 1 foot 6 inches respectively.

W. H. D.

* These and a few more forms obtained in the lowest beds are included in the Lower Lias.

† Obtained in clay near base of workings by Mr. Rhodes on a subsequent visit.

‡ *Ammonites margaritatus*, got 3 feet above floor of Bracebridge pits by myself and Mr. A. Macconochie.—JOHN RHODES.

In April 1885 the following section of the beds was exposed in Kirk and Parry's pit :—

		Ft.	Ins.
Surface, reddish-brown sand	-	1	6
Ferruginous rubble, suggesting a thin weathered representative of the Marlstone Rock-bed	-	about	0 6
Grey shale	-	3 ft. to	4 0
Ferruginous septarian nodules	-	-	0 4
Grey shale	-	-	1 8
Nodule bed	Hard cement-stone nodules and ferruginous concretionary bed with phosphatic concretions at top and bottom	-	about
	-	-	3 0
Grey shale, ferruginous in places, exposed down to water filling the bottom of the pit, a thickness of	-	-	18 0

About 10 feet from the surface I obtained an Ammonite on the side of the pit, and at about 14 feet from the surface, a good-sized fragment of fossil wood in the clay. The nodule-bed in this pit is, doubtless, the same as that similarly denominated in the Bracebridge Brick Company's pit.

The following is a list of fossils collected by Messrs. Rhodes and Macconochie from Kirk and Parry's pit, Bracebridge :—

Wood.

Crustacean fragment.

Avicula cygnipes, Phil.

A. inæquivalvis, Sow.

Inoceramus.

Ostrea irregularis, Münster.

Pecten liasinus, Nyst.

Astarte.

Arca Stricklandi, Tate.

Cardium truncatum, Sow.

Goniomya.

Hippopodium.

Leda imbricata, S. & N.

L. graphica, Tate.

Chemnitzia?

Eucyclus imbricatus, Sow.

Ammonites margaritatus, Montf.

A. nitescens, Y. & B.

A new road, called West Parade Road, was being made in the west part of Lincoln in April 1885. A drain running down the middle of it showed bluish-grey micaceous clay, in places containing fragments of Belemnites, and friable specimens of small Ammonites. A list of fossils obtained by Mr. Rhodes is given below. In one place the drain was open to a depth of 8 feet, and ferruginous nodules were visible at 2 or 3 feet from the bottom.

Drain in new road, Lincoln, to be called West Parade :—

Wood.

Ostrea.

Lima.

Pecten.

Modiola scalprum, Sow.

Eucyclus imbricatus, Sow.

Ammonites margaritatus, Montf.

Belemnites.

Adjacent is Mr. Foster's old brickyard in which no exposure is visible. *Plesiosaurus* ? sp. was obtained from this pit by Mr. Fowler.

The following notes are by Messrs. Dalton and Penning :—

The septaria taken from Mr. Foster's old brickyard, south of the Lincoln racecourse, are like those of the Bracebridge Brick Company's pit, and the section was probably on the same horizon. Mr. Penning records, under the usual covering of sand with ironstone debris, 15 feet of blue clay. No exposure is now visible.

W. H. D.

A little to the north of the racecourse is an old brickyard, formerly worked by Mr. Glasier, and though now somewhat obscured by talus, admitting of the following observations :—

18½ feet - { Blue clay.
Nodular ironstone, 6 to 9 inches.
Grey shaly clay.
Nodular ironstone with phosphatic pebbles.
Blue clay, 9 feet.

There is a perceptible dip to E. by N.

W. H. P.

For the new Gas Works in the south part of Lincoln, by the road to Bracebridge, a large pit had been sunk to a depth of about 20 feet, which is now walled round (April 1885). The refuse by the side consists of bluish-grey clay, with nodules, in which Mr. Rhodes obtained *A. heterogenus*, Y. & B.

Between the Barracks, near Lincoln Mills, and the Race Ground, exceptional opportunities for observing the beds that crop out on the escarpment of the Inferior Oolite, on the north of Lincoln, are afforded by Swan's pit, in which about 90 feet of Upper Lias is exposed beneath the basement bed of the Inferior Oolite. From the bottom of Swan's pit, tram rails are laid for 5 or 6 chains downward across a feature suggestive of landslip. At and near the bottom of the tram, an arenaceous bed containing *A. serpentinus* is shown in shaly clays, belonging to lower beds in the Upper Lias than those exposed in the pit. The ground falls more gently from the bottom of the tram for 4 to 5 chains to the east end of Glasier's pit, which affords a partial exposure of 15 feet of grey Middle Lias shales with ferruginous nodules. On the floor of the pit at 4 chains from the east end a ferruginous nodular band is shown (the same as the lower bed in Mr. Penning's section). From this point to the road where the pit terminates, a distance of 9 chains, the floor of the pit is some feet below the nodular band; bluish clay is evidenced, but no section exposed in this part of the pit.

Mr. Rhodes obtained the following fossils from limestone nodules in the Middle Lias clay in Glasier's pit :—

Crinoid stem and ossicles.

Lingula.

Avicula inaequalis, Sow.

Pecten.

Arcomya?

Cardium.

Goniomya.

Gresslya.

Gasteropod.

Ammonites.

Belemnites.

From Willoughton Grange, northward, we obtain indications, slight, it may be, but relatively important, of the position of the Pecten Bed, which has been taken in Sheet 86 as the basement bed of the Middle Lias.

In a ditch by the path from Willoughton Grange to Willoughton indications of an ironstone bed were observed.

At the northern border of Sheet 83 (W. Long. 0° 36' 55'') signs of the outcrop of the Pecten Bed were noticed, in line with its strike in the southern parts of Sheet 86.

With these two observations, solely, for our guidance, it is only possible to guess at the prolongation of the boundary line.

Just south of Fillingham both the Rock-bed and underlying clay are concealed by Boulder Clay, but from Fillingham Lake to Hemswell a band

of Middle Lias Clay forms the surface at the foot of the feature made by the Rock-bed. This band attains its maximum width south of Glentworth, where the clay is exposed in a large disused brick-pit (a quarter of a mile south-west of Glentworth Church): the section consists of bluish-grey shaly clay with flat cake-like pieces of cement-stone and ferruginous concretions.

In the ironstone nodules the fossil collector obtained *Nucula* and *Actæonina*, specifically indeterminable.

Between Blyth Close and Harpswell stiff grey clay is exposed in a small pit on the Rock-bed feature; it is either the Middle Lias Clay exposed through the denudation of the Rock-bed, or a drift-clay in association with the sand which obscures the relations of the beds in the vicinity.

The next section in the clay band just below the Rock-bed is a brick-pit, now being worked, on the north side of the high road south of Hemswell, in which the uppermost part of the Middle Lias Clay consists of bluish grey shaly clay with cement-stone nodules, irregular, and partly ferruginous. This pit proved to be fossiliferous, the following specimens having been obtained from ironstone nodules in the clay:—

Lima pectinoides, Sow.
Cardium truncatum, Sow.
Leda (*n. sp.*).
Pleuromya.
Ammonites.
Belemnites.

Although it was in the last degree important that the *Ammonites* in this list should be specifically determined, their unsatisfactory condition precluded it. The same disheartening remark applies to the greater part of the specimens obtained from the Lias beds generally in the northern part of Sheet 86. Great pains spent in discovering fossils in beds where their determination is in the highest degree important, but where their preservation is normally bad, have been thus rendered nugatory.

In one part of the pit signs of the base of the overlying Rock-bed were noticed.

The clay in the bottoms of the ditches between Hemswell and Willoughton may be in part Middle Lias, but the evidence is very unsatisfactory. Middle Lias Clay is evidenced at the surface by ponds and in ditches, just below the Rock-bed, between Willoughton and the Blyborough Valley: on the north of the Blyborough Valley it is concealed by Drift. In the road just north of Willoughton the clay is exposed below the Rock-bed.

MARLSTONE ROCK-BED.

Mr. Dalton observes:—

Though the feature of the Marlstone is well marked, and fragments of it are seen at intervals between Burton and South Carlton, the first exposure of the actual rock in place is about 300 yards north of the church of the latter village. Here the denudation of the overlying clays has left the outcrop of the rock at a lower level than its base on the escarpment to the west, and a spring is the result. In the next field the path between the Carltons crosses a ditch showing the full thickness (about 5 feet) of the rock. Besides native fossils, the rock here contains many phosphatic pebbles and slightly-worn slabs of fossiliferous stone, in which, however, no determinable species were found, though the outline of the casts suggested *Cardinia* and other Liassic genera.

W. H. D.

The following is a list of fossils obtained from the Marlstone Rock-bed in the ditch above mentioned:—

Terebratula.
Avicula.
Gryphæa? (fragment).
Pecten æquivalvis, Sow.
P. liasinus, Nyst.
Lima, (fragment).
Cardium, (young).
C. truncatum? Sow.

Cardinia crassiuscula, Stutch.
Lithodomus.
Unicardium cardioides, Phil.
Chemnitzia semitecta ? Tate = *C. sublineatum*, Moore.
Pleurotomaria, fragment.
Belemnites breviformis, Voltz.

Mr. Dalton says :—

In the little brook at North Carlton the base of the rock is seen, and close by is a small hole whence walling stone and road metal have been extracted ; the contained iron here forms numerous concretions constituting a large part of the mass.

The rock is again seen at Aisthorpe, and at Cammeringham.

W. H. D.

The Rock-bed is exposed under Boulder Clay in the stream half a mile south of Fillingham and a mile and a half west of the Ermine Street near Ancholme Head.

The following fossils were obtained from the ironstone :—

Terebratula.
Pecten substriatus, Röm.
Cardinia Listeri, Stutch.
Ammonites communis, Sow., two specimens.
Belemnites.

The Rock-bed is exposed at the surface in the village of Fillingham, and in a pit near the southernmost houses on the west, in which *Terebratula punctata* and *Waldheimia perforata* were obtained.

At about 30 chains north of Fillingham Church, a small pit exposed 3 feet of brown stone, grey and crystalline in places, broken in the upper part, containing Belemnites ; the section is partly covered by 6 inches of soil with ferruginous fragments of the rock.

In this tract, between Glentworth and Fillingham, the Rock-bed makes a considerable dip-slope, which may be masked in places by a Boulder Clay soil from 2 to 3 feet in thickness. The shaly ironstone is exposed in a ditch by the path between the villages to a depth of from 3 to 4 feet, at about half a mile from Glentworth. At a quarter of a mile, south of Glentworth, a foot of red-brown shaly ironstone was exposed under the roots of a tree.

At Glentworth the Rock-bed is generally evidenced by red-brown concretionary fragments and small pieces of decomposed rock.

Near Harpswell on the south, the Rock-bed was visible, and its base was seen in the vicinity of the brick-pit, south of Hemswell.

In Hemswell village, west of the church, the superficial extent of the Rock-bed is very doubtful, as, where the made-ground terminates, Boulder Clay commences, and there is no feature for the outcrop of the bed ; at the turning near the schoolhouse, beds which might be the Rock-bed *in situ*, were visible just below a section of Upper Lias exposed in draining.

Between Hemswell and Willoughton the soil is sandy and loamy, and although there is some feature for the outcrop of the Rock-bed at its junction with the Upper Lias, its westward extension is unmarked by feature. In this tract at 54 chains from Willoughton Church, a short distance west of the blind road towards Hemswell, indications of the Rock-bed, in the form of rubbly ferruginous fragments on clay, were noticed by a pond. A few chains further north the Rock-bed is said to have been proved under about 3 feet of sandy Drift. If the sandy Drift of this tract is a modification of the outskirts of the Boulder Clay, largely due to the wearing away of the Rock-bed, it would be impossible to say how much of the bed had been spared beyond its line of outcrop, and its destruction would account for the absence of a line of feature on the west.

Under the houses near the blacksmith's shop in Willoughton, brashy ironstone is visible *in situ*. Ironstone is also evidenced at the most westerly Farmhouse in Willoughton, and it is exposed by the road to Blyborough, just north of the stream at Willoughton. Between Willoughton and Blyborough, and north of Blyborough, the Rock-bed is evidenced by feature and surface indications.

CHAPTER VI.*

UPPER LIAS.

The following introductory notes on the Upper Lias are by Mr. Dalton :—

The narrow belt of Upper Lias Clay in this district affords over the greater part of its length no sections, but in the neighbourhood of Lincoln the entire series is laid open in a single deep pit (that of Mr. Best at Bracebridge), and more than half of it in the pit on the North Cliff belonging to Messrs. Swan Bros. and Bourne. The only author who has described these instructive sections is Mr. W. D. Carr, who in 1883 communicated a short notice to the "Geological Magazine." To him is due the credit of detecting four out of the five zones into which the thicker series of Rutland has been divided by Professor Judd, the upper zone having been removed by denudation from this area: in fact, the transgressive overlap of the Inferior Oolite across the bedding planes of the Lias, can be detected by careful measurement, within the width of Messrs. Swan's pit.†

The subdivisions remaining are as follows :—

- d. Black fissile shales with bands of ferruginous and calcareous nodules. Zone of *Ammonites bifrons* about 40 feet thick.
- c. Black shales with beds of comminuted shells, in which are many small whole gasteropoda and lamellibranchs, *Trigonia pulchella* and *Nucula Hammeri* being characteristic. The principal Ammonite is *A. communis* of which various modifications occur, but which in this area is confined to this zone, 8 feet thick.†
- b. Thick-bedded black and blue micaceous shales with bands of septaria and broken shell, the uppermost of the latter being characterized by an undescribed species of *Lucina* and by fine specimens of *Belemnites subtennis*. The principal Ammonites are *A. serpentinus* and *A. heterophyllus*. 40 feet thick.
- a. Laminated black shales with two or three impersistent beds of argillaceous limestone, the "Fish-and-Insect Limestones," Dumbleton Beds (Prof. Judd).

W. H. D.

At Lincoln the Upper Lias seems to be about 100 feet in thickness; it probably attenuates northward to about half that thickness in Sheet 86. To the north of Fillingham the exposures are too few and insignificant to enable one to trace the horizons given above.

A section of Harpswell Hill is given in "The Memoirs of William Smith," by J. Phillips, 8vo., London, p. 97. Blue Clays of the Upper Lias were exposed to a depth of 20 feet.

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

† Mr. Dalton's views as to the unconformity at the base of the Oolites, and as to the range of *A. communis* are not shared by me. For all his statements respecting the position of Ammonite zones he is individually responsible.

In the brickyard half a mile east-north-east of Navenby Station, the following section, showing the so-called "Fish-and-Insect Limestones," was observed by Mr. W. H. Penning.

Yellowish calcareous and sandy shale, the bedding planes crowded with <i>Inoceramus dubius</i> (fragments of the chitinous shell of which resemble scales of fish and elytra, &c. of insects)	-	-	-	-	-	1 foot.
Grey shaly clay	-	-	-	-	-	2 feet.
Thin sandy dark-coloured limestone	-	-	-	-	-	1 foot.
Finely laminated shale	-	-	-	-	-	3 feet.
Nodular bed with Ammonites.						
Shales	-	-	-	-	-	2 feet.
Thin sandy dark-coloured limestone.						
Paper shales.						

W. H. P.

The section, as observed by Mr. Dalton in 1883, was somewhat different, viz. :—

						Ft.	In.
Limestone	-	-	-	-	-	1	0
Shales	-	-	-	-	-	4	8
Limestone	-	-	-	-	-	0	4
Shales	-	-	-	-	-	6	0

Ammonites annulatus, *A. communis*, &c. occur abundantly throughout.

The following notes are also supplied by Mr. Dalton :—

In an old brickyard below Coleby, the pit face, though much concealed by grass and talus, shows the shelly bed at the top of the *A. communis* belt. It here contains very little comminuted shell, consisting principally of *Pleuromyæ*, *Nuculæ*, *Ammonites*, and *Belemnites*, closely packed in clay for about 8 inches in depth.

The fine section of Mr. Best's brickyard fully atones for the scarcity of exposures southward. Here, as has already been mentioned, is a continuous section of the entire thickness of the Upper Lias. The Northampton Sand ironstone is seen to a thickness of 8 feet at the top, below which comes the following series :—

						Ft.	In.
Zone of <i>A. bifrons</i>	Clays	-	-	-	-	37	9
Zone of <i>A. communis</i>	{ <i>Trigonia</i> bed	-	-	-	-	2	3
	{ Clay	-	-	-	-	5	8
	{ <i>Lucina</i> bed	-	-	-	-	2	0
Zone of <i>A. serpentinus</i>	{ Clay	-	-	-	-	1	2
and	{ Shelly bed	-	-	-	-	0	2
<i>A. heterophyllus</i> .	{ Clay	-	-	-	-	38	0
	{ Shelly bed	-	-	-	-	1	6
	{ Shale	-	-	-	-	2	0
Zone of <i>A. annulatus</i> .	{ Irregular concretionary limestone	-	-	-	-	1	0
	{ Shale	-	-	-	-	5	0
	{ Argillaceous laminated limestone	-	-	-	-	1	6
	Dark blue shales	-	-	-	-	12	0
						110	0

The uppermost beds of the series are again seen in the road cutting west of Canwick, and in a pond below the workings of the Mid-Lincolnshire Iron Company between Greetwell and Lincoln. In the crumbling clay thrown out of this pond occur many crystals of selenite, probably originating from the combination of sulphuric acid in the clay with calcareous water percolating from the Oolite above.

In the town of Lincoln the Upper Lias is only exposed occasionally in sewers and foundations, but about a mile to the northward, at the point where

Lincoln Mills is engraved on the Map, Messrs. Swan Bros. and Bourne have a pit showing the following fine section :—

				Ft.	In.
		Oolite limestone	- - -	8	0
		Ironstone	- - -	4	6
Zone of <i>A. bifrons.</i>	{	Clays -	- - -	22	7
		Shelly bed	- - -	0	4
		Clays -	- - -	8	1
		Shelly bed, <i>Trigonia</i> or <i>Nucula Ham-</i> <i>meri</i> bed	- - -	1	4
Zone of <i>A. communis.</i>	{	Shale -	- - -	0	6
		Shelly bed	- - -	0	8
		Shale -	- - -	4	4
		Shelly bed	- - -	0	8
		Shale -	- - -	2	6
Zone of <i>A. serpentinus</i> and <i>A. heterophyllus.</i>	{	Shelly bed, <i>Lucina</i> bed	- - -	1	6
		Shale -	- - -	1	1
		Shelly bed	- - -	0	4
		Shales	- - -	0	3
		Double row of septaria in shales	- - -	1	6
		Shales -	- - -	10	0

The full thickness of the Upper Lias at this point is 100 feet; the slope, from the floor of the pit to the flat marking the top of the Middle Lias, being 36 feet in height. The dip, which is to the north of east, will scarcely affect this measurement. The *Lucina* bed at one point was consolidated into a lenticular mass of limestone, unlike the septaria that abound in the shales, being of compact and crystalline texture.

A pit was sunk in the floor of the brickyard to test the downward extent (!) of the clay; it was carried to a depth of 50 or 60 feet, ending in hard micaceous shale with a fissure full of foul air under pressure. It will be noticed that no mention is made of meeting either the limestones of Mr. Best's pit or the Marlstone Rock-bed of Burton, but either of these might be ignored by a sinker as merely septaria of unusual size, and the depth as well as the character of the lowest beds reached imply that the excavation ended in the Middle Lias Clays.

W. H. D.

From Fillingham northward the Upper Lias Clay can be traced with facility, owing to its position on the slope of the Cliff, or Oolitic escarpment, beneath the basement beds of the Oolite, down to the flattish ground on which the Rock-bed of the Middle Lias crops out. The Upper Lias is nowhere exposed in continuous section, and the outcrop of the lower part of the division between Fillingham and Glentworth, and between Glentworth and Harpswell, is concealed by sandy soil, probably to a great extent derived from the waste of Lower Estuarine Beds. The lower part of the Upper Lias is similarly concealed between Hemswell and Willoughton and in Blyborough Park.

The Upper Lias, where visible, consists of bluish-grey finely laminated shales. It is exposed by a pond just south of Harpswell; in the roadside ditch in the north part of Hemswell Village, which is the most continuous of its exposures; and by a pond near Willoughton on the north-east. No fossils were obtained from these exposures.

CHAPTER VII.*

THE LOWER OOLITES.

INTRODUCTORY.

The Lower Oolites in the area under description consist of seven members, bracketed into two main groups as follows:—

Great Oolite Series.	{	Cornbrash. Great Oolite Clay. Great Oolite Limestone. Upper Estuarine Series.
Inferior Oolite.	{	Lincolnshire Limestone. Basement Beds:—consisting of the Lower Estuarine Series and the Northampton Sand (Dogger).

Of these divisions the Lincolnshire Limestone occupies by far the largest area in Sheet 83: it rests on the Basement Beds at the crest of the escarpment (or the Cliff, as it is often called) whence the surface declines gently to the foot of the low escarpment made by the Great Oolite Limestone resting on the softer beds of the Upper Estuarine Series. The Great Oolite Limestone, in its turn, occupies a surface falling gently eastward to the outcrop of the Great Oolite Clays, which form the outcrop slope of the low escarpment dominated by the Cornbrash.

South of the Witham valley, at Washingbrough, the regularity of the features made by the members of the Great Oolite is interrupted in places by faults and obscured by superficial deposits. To the north of the Witham Valley the features of the Great Oolite divisions continue in almost unbroken succession.

INFERIOR OOLITE.

Basement Beds.

The Basement Beds include the strata intervening between the lowest limestones of the overlying beds and the Upper Lias Clays. These beds consist of the Northampton Sand and the overlying clays, shales, and sands of the Lower Estuarine Series. In the northern part of Sheet 83, where the Basement Beds begin to assume the types by which they are characterised in Sheet 86, the Northampton Sand is represented by a hard ferruginous bed called the Dogger, and the Lower Estuarine Series is overlain by a compact limestone bed, called the Hydraulic Limestone in Sheet 86 and included in the Basement Beds. In the northern part of Sheet 83, probably on the Escarpment above Hemswell, the Hydraulic Limestone either dies out or is represented by a bed or beds which do not present its distinctive characters, and would, therefore, be included in the Lincolnshire Limestone.

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

The following observations on the Basement Beds are by Mr. Dalton:—

The different names applied to this set of beds, viz., Northampton Sand; Lower Estuarine Series; or Basement Beds—denote varying lithological characters, the first being applied to massive ironstone; the second to clays and loams; and, the third to the more heterogeneous series in the northern part of the district. They are necessarily combined on the Map on account of their small development, and even so are barely capable of delineation upon the one-inch scale at points where the surface-slope is steep, although commercially the series is one of the most important in the district of Lincoln.

These beds bear the ironstone facies, with occasionally a foot or two of grey clay at the top from Navenby to Burton, varying in thickness from 4 to 18 feet, and resting on an irregularly-eroded surface of the Lias clay, fossils and phosphatic nodules from which occur in a rolled and abraded condition in the lower beds of the ironstone.

Between Burton and Ingham the clays and non-ferruginous sands prevail, to the partial or complete exclusion of the ironstone, the change being gradual, by intercalation of the valueless material and northerly attenuation of the several beds of ironstone. The reader is referred to Prof. Judd's memoir on Sheet 64 for a full account of the structure, composition, and probable origin of this interesting rock.*

ANALYSES of the Ironstone of the Northampton Sand.

—	A.	B.	C.	D.	E.	
Peroxide of iron - -	58·06	38·18	30·83	37·00	44·13	
Protoxide of manganese	0·02	0·03	0·03	—	0·30	
Alumina	6·10	7·00	2·48	4·00	5·73	
Lime - - - -	2·94	2·20	2·91	14·25	4·06	
Magnesia - - -	0·89	Trace	Trace	—	0·38	
Silica - - - -	13·17	38·10	51·14	21·00	23·61	
Sulphur - - -	Trace	0·02	0·02	—	0·43	
Phosphoric acid - -	0·80	1·62	0·69	—	1·39	
Carbonic acid	1·87	} 13·05	12·20	20·00	} 12·40	
Water, combined	11·86			} 3·75		
„ hygroscopic -	4·29					
Total -	100·00	100·20	100·30	100·00	99·93	
Metallic iron, per cent. - -	40·5	26·73	21·58	26·	—	
„ in samples as received -	—	—	—	—	31·45	
„ in calcined stone	—	—	—	—	38·57	

A. Very rich nodule of Waddington Red Ore.
 B. Average of lower bed of same.
 C. „ upper „
 D. Coleby Blue Ore.
 E. Lincoln, by J. Pattinson, in Messrs. Daglish and Howse's paper.—
Trans. N. Engl. Inst. Eng., vol. xxiv., pp. 23–33 [1875].

From
 Capt. J. G. Macdakin
 (by letter).

* The Geology of Rutland (Geol. Survey Memoir), 1875, pp. 90–138.

E. was dried at 212°, losing 7·5 per cent. of hygroscopic water. For comparison with the other analyses, the percentages given have been reduced in the same proportion.

W. H. D.

To the north of Ingham, the Basement Beds are better developed in Sheet 83 than in Sheet 86, although we cannot obtain indications of an individual limestone for the top resembling the Hydraulic Limestone, except in the northernmost part of 83, near Willoughton Mill, and to the north of it.

The Basement Beds north of Ingham consist of—

Lower Estuarine Series	{	Sands partly cemented into 'pan'
		and irregularly associated with dark grey clay.
Dogger	-	Hard brownish sandstone.

Southward of Coleby the ironstone was worked for a time from a section, showing the following divisions, as noted by Mr. Penning:—

	Ft.	In.
Fine-grained oolitic limestone	-	5 0
Sandy ferruginous limestone, partially converted into ironstone	-	1 6
Sandy clay	-	0 9
Ironstone	-	6 0
Blue Lias clay	-	-

The dip here is southward at about 2°.

The following section of these beds is given by CAPT. MACDAKIN* of a shaft sunk at Coleby:—

	Ft.	In.
Oolitic limestone	-	35 -
Peroxide bed	-	8
Clay ironstone	-	4
Hard carbonate of iron	-	9
Clay parting	-	4
Hard blue carbonate of iron	-	4
Peroxidised band	-	10
Nodules and clay partings	-	11
Blue ferruginous sand bed	-	1 1
Ironstone nodules	-	6
Clay with nodules (micaceous)	-	3 0
Coprolites and pyrites	-	3
Blue Lias clay	-	-

“The ironstone beds vary in richness and in their mineral characteristics; whilst the upper beds are siliceous, the lower beds are more argillaceous. Some of the richer bands contain as much as 40 per cent. of iron, which in the more siliceous portions falls to 28 per cent. The ore near the outcrop occurs in nodular masses on an average, perhaps, of a foot in diameter, sometimes as geodes with concentric bands of oxidation, and occasionally containing a loose kernel of unoxidised blue carbonate of iron. For 200 yards from the outcrop, the beds are of a deep reddish-brown colour; then changing into the bluish-grey carbonates; the red ore occasionally lining fissures plainly showing the cause of this change from the original blue carbonate by oxidation to the brown clay ironstone nodules of the outcrop, which even still, in some places, exhibit on fracture a centre of the original blue carbonate of iron. Some portions of the peroxidised beds are very vesicular, the wellsinkers having from time immemorial called it ‘Firestone,’ believing it to have been the work of subterranean fires.”

* *Geological Magazine*, Dec. ii., vol. iv., pp. 406–410. (1877.)

Mr. Penning remarks that :—the ironstone was at one time worked on the north of Waddington, almost due east of the station. Here, under 5 or 6 feet of thin-bedded Oolite, was a bed of finely laminated clayey sand, from 12 to 18 inches in thickness, resting on concretionary ironstone 9 feet thick. In the blue clay below, a discontinuous nodular band of ironstone, or ferruginous septaria, was observed at about a foot from the upper limit of the clay.

At Bracebridge eight feet of ironstone is seen at the top of Mr. Best's brick pit, resting on the Lias, and a pond on the west side of the high road, opposite White Hall, shows a foot of yellow sandstone over a foot of light-manve-coloured sand, both containing plant-markings.

Three furlongs west by north of Sheepwash, or three-quarters of a mile east by north of Canwick, the ironstone is exposed in the following section :—

						Ft.	In.
Rubbly limestone	-	-	-	-	-	3	0
Brown sand, clayey at base	-	-	-	-	-	0	6
Ironstone	-	-	-	-	-	9	0
							W. H. P.

The following observations are made by Messrs. Dalton and Penning :—

The railway-cutting south-west of Washingbrough crosses obliquely two slight undulations of the beds, producing two artificial inliers in the floor of the cutting. The eastern inlier runs from the bridge a quarter of a mile south-west of Washingbrough church for 280 yards to the north-west; of this, 200 yards is composed of ironstone in contact with the Oolite on the south, and 130 yards on the north side of the line, four feet of the ironstone being seen at the highest point. At the extreme east of the inlier, 23 inches of clay separates the ironstone from the Oolite above. The western end of this inlier consists of grey clay for 80 yards on the south, and 150 yards on the north side. An interval of 120 yards separates this from the western inlier 200 yards long, and rising 3 feet above the rails, all clay.

A little more than a mile E.N.E. of the Cathedral a number of strong springs rise in a tiny combe about 200 yards south of the Wragby road. The sides of this hollow have lately, 1884, been proved to consist of ironstone, as was previously suspected. Fragments of this rock occur in the soil to within 40 yards of the road, on the west of the fault which brings up the Lias to produce these springs. Half a mile to the south-east is an extensive open-work belonging to the Mid-Lincolnshire Iron Company. Here 16 feet of ironstone, mostly peroxidised, but partly blue- or green- hearted, is quarried into a tramway, extending along the floor of a trench, of which one side is the unmoved ore, with a capping of 10 to 12 feet of oolitic rubble, the other a bank of the same rubble, rising to the level of the top of the ironstone. Successive widths of the ore are cleared of the capping, which is carried on planks across the trench, which is then moved to the west by the quarrying away of the shelf of ore. Though the ground rises westward, the rise of the beds is for the present so nearly equal, that the capping is not increasing in depth as the work proceeds, whilst further up the hill the ore has been reached by tunnel-mining, and considerable areas have been worked out, and the overlying rock allowed to fall in by the removal of the timbering. The lower 2 feet of the ironstone is so crowded with phosphatic nodules as to be worthless for smelting, whilst its hardness has deterred the makers of phosphatic manures from attempting to utilize it as a source of phosphoric acid, although by weathering the ferruginous matrix soon breaks up and frees the nodules. In the road below the workings, and about 100 yards west of the brook, is seen a breccia of angular fragments of ironstone and oolite in a fine calcareous paste. This is the fault-rock of the fault before referred to, which throws down the Oolite on the east, and by bringing it into juxtaposition with the Lias on the west, has presented the line of weakness now represented by a side valley practically along the fault.

South of the road are minor open-works under the same owners, and the entrances to the tunnel-mines range all along the escarpment nearly to the Hospital.

The aspect of the face of ironstone varies much from local causes. The blue or green nuclei are sometimes very large, extending to within a few

inches of a joint- or bedding- plane; at other times they are absent altogether, the rock being peroxidised throughout. Sometimes the cellular structure is strongly pronounced; other portions being nearly homogeneous. A bed of grey clay, varying from a foot thick down to nothing, separates the ironstone from the Oolite, and calcareous infiltrations from the latter sometimes coat the joint faces of the ironstone with tufaceous films.

W. H. D.

The ironstone has been proved by boring to continue eastwards, but is not at present worked, having 65 feet of Oolite above it.

One of the minor open-works mentioned above shows the following section:—

	FEET.
Brown sandy loam, full of broken ironstone	- 8
Brown sandy loam, without ironstone	- 2
Grey clay, with many phosphatic nodules	- 1
Dark blue clay (Lias).	

The Monks' Abbey Quarry, on the escarpment north-east of the ruins, shows the following beds:—

	FEET.
Rubble - - - - -	- 3
Thin-bedded limestone - . - - -	- 4
Hard sandy limestone - - - - -	- 1
Marl - - - - -	- 1
Compact ironstone - - - - -	- 8

W. H. P.

It is uncertain whether these accounts refer to sections still open, as in the progress of the works exposures are perpetually obliterated and replaced by fresh cuttings.

Eight feet of good ironstone may be seen at the north-east corner of the Arboretum, and the rock has been exposed in sewers and foundations, everywhere through the town to the Union.

W. H. D.

Under the cricket field on the Wragby road, the Oolite cap is 45 feet thick, and the ironstone 6 feet, all blue stone.

In the large clay pit on the north cliff, belonging to Messrs. Swan Brothers and Bourne, the following series of beds is seen above the Lias Clay (which has already been described, p. 35).

	FEET.
Rubbly limestone - - - - -	- 4
Hard limestone - - - - -	- 1
Northampton Sands.	{ Ironstone with a few phosphatic nodules and derivative fossils, sandy at base in places - - - - -
	{ Thin intermittent bands of light mauve-coloured clay.
	{ Ironstone, crowded with phosphatic nodules.
	{ Blue Lias clay.

The pale mauve or violet clay, here interbedded with the ironstone, expands northwards to a thickness of, possibly, 20 feet at Burton.

In the by-road leading to an Oolite quarry, due east of Burton church, light mauve-coloured clay and loam are seen to pass under ironstone, 1 foot thick. At another point in the road the following section is seen:—

Limestone.
 Ferruginous sands, about 6 inches.
 Ironstone.
 Violet-coloured loam.

At the spring, north of Burton Mill, ironstone is seen to a thickness of 6 feet, though possibly there may be a little slipping of the hillside at this

point, and the rock seen may be out of its true position. The uppermost part of this series is exposed in a small quarry above this, showing—

	FEET.
Lincolnshire { Rubbly limestone - - -	3
Limestone { Grey, slightly oolitic limestone -	2
Lower Estuarine clay, with nodules of ironstone.	

At the branch roads south-east of South Carlton, violet-coloured loam is seen in the road-cutting; ironstone is exposed above this.

W. H. P.

The loamy sands have been dug above Cammeringham.

W. H. D.

From Ingham Heath northward to Glentworth, the position of the Basement Beds is sufficiently well indicated without actual exposure, by the steeper upper part of the escarpment slope, by occasional sandstone fragments on the surface, and by ponds in the underlying Upper Lias Clay. The upper boundary, owing to the presumable absence of the Hydraulic Limestone, is not so certain, but the uppermost bed of the Lower Estuarine Series sufficiently indicates its position.

The turning to Glentworth shows the following section under hard limestone, partially exposed :—

	Ft.	In.
Grey loam and clay, with ironstone nodules in the upper part - - -	1	6
Yellowish and buff sand, with greyish seams, about -	2	0
Grey clay, apparently on grey moist sand, both together being about - - -	2	6
Grey loam and sand, partly indurated, containing ligneous matter - - -	2	0
Yellowish, buff, and whitish mottled sand, about -	2	0

This would give an exposed thickness of 10 feet to the Lower Estuarine Series, and as the Upper Lias appears to be about 10 feet, or more, below, it is probable that the Basement Beds are from 20 to 25 feet thick.

A soil of buff clay with bits of limestone, about a foot in thickness, rests upon the outcrop of the upper bed, and upon the outcrops of the succeeding beds brown sand and gravel patches are visible.

In the late Professor J. Phillips' Memoirs of William Smith, p. 97, a section of the Oolitic escarpment at Harpswell, as recorded by the latter, is given. It is probable that the great thickness of beds between the 20 feet of Upper Lias, exposed, and the Lincolnshire Limestone, was assigned to them from observations made in neighbouring localities, and not in one successive exposure, as we have no evidence of a greater thickness of Basement Beds than 30 feet in this neighbourhood. The section is as follows :—

	FEET.
l. White limestone (oolite) - - -	30
k. Whitish clay and sand - - -	12
i. White sand - - -	3
h. Sandy with iron balls - - -	10
g. White micaceous sand - - -	3
f. Brown sands - - -	4
e. Clay parting.	
d. Brown sandstones and shells - - -	30
c. Blue clays, 20 feet exposed.	
b. Marlstone Series.	
a. Lias Clays.	

No doubt the road cuttings presented greater facilities for observation when the above section was taken, and the lithological descriptions are valuable :—

c. represents a part of the Upper Lias.

d. is the Dogger, or representative of the Northampton Ironstone, its thickness as applied to this district is enormously exaggerated.

e. to k. inclusive, show the composition of the Lower Estuarine beds.

l. is the lower part of the Lincolnshire Limestone.

The estimate of the thickness of l. being evidently a general one, the thicknesses of the subjacent beds cannot be taken as absolute.

By the high road on the north of Harpswell, beds of soft buff micaceous sand-rock, split up by numerous joints, and shaly in places, are exposed to a depth of 5 feet, and are also shown in a small pit adjacent. The beds may have a dip to the east of 2° , but this is uncertain. There are indications of Upper Lias Clay in the road at about 5 feet below the sandstone exposures.

In a farmyard by Harpswell church, about 10 feet of similar buff sand-rock, apparently dipping in an easterly direction, is exposed by a pond; above it there is evidence of grey and buff loam.

By the turning to Hemswell the Lower Estuarine beds are partially exposed. They consist of grey clay with a violet tinge and shaly tendency, upon yellowish sand and sandy loam, with brown and buff sand-rock or sandstone, broken and more or less nodular.

The best section of these beds is afforded by the exposure at Hemswell well, where yellowish-brown ferruginous sands, occasionally associated with clayey matter, about 15 feet thick, would appear to constitute the Lower Estuarine Series, the Dogger below it being from 10 to 15 feet thick, and composed as far as visible of—

	FT. IN.
Pale grey and yellowish, tough, siliceous rock, with lateral joints or bedding lines in places, about	1 6
On beds of softer material, with ochreous brown fossiliferous matter	2 0
Upon yellowish-brown, tough, friable, bedded sand-rock, about	5 0

The base cannot be far beneath the last-mentioned bed the point at which the water issues. There may be 2 feet of Dogger above the uppermost bed.

To the north of Willoughton Mill the Basement Beds occupy a considerable area, but it is not possible to separate the Dogger, which may be from 15 to 20 feet thick, from the Lower Estuarine Series. The Lower Estuarine beds appear to contain much clay in their upper portion, partially exposed by the sides of ponds. In this district, also, fragments of what, in Sheet 86, we should call Hydraulic Limestone, occur on the surface, although no Hydraulic Limestone is exposed in section, unless represented by a hard greyish-brown siliceous limestone observed in a ditch. We have felt justified in separating the capping bed of a hill, extending southward toward the letter *h* of the word Willoughton on the Map, from the Lower Estuarine beds beneath, and from beds of the Raventhorpe, Low Santon, and Winterton types (*i.e.*, beds above the Hydraulic Limestone in Sheet 86) above; but these lines for the representative of the Hydraulic Limestone cannot be drawn beyond a point about half way between Willoughton and Hemswell; the Lower Estuarine beds consist of grey clay and white and yellowish sand, as far as their composition is observable.

In Blyborough Park the Dogger is exposed in the plantation, and portions of it have also been noticed in the roots of trees blown down in the Park, after severe gales. It consists of soft, brown, broken, ferruginous sandstone, very rubbly. As far as one can judge from ponds on the south of, and near the letter *h* of the word Blyborough on the Map, the Lower Estuarine beds consist of whitish sand and clay.

Between Willoughton and the northern margin of Sheet 83, much of the Upper Lias slope is concealed by sand, probably débris from the Dogger and Lower Estuarine beds, the arenaceous character of these beds will also perhaps account for sands obscuring the lower part of the Oolitic escarpment between Willoughton and Hemswell, between Harpswell and Glentworth, and on the north of Fillingham.

THE LINCOLNSHIRE LIMESTONE.

From the great superficial breadth of the Lincolnshire Limestone area, south of Lincoln, it has been found convenient to describe the sections on the west of the Roman Road first, and then those which lie to the east of it. The same valuable topographical landmark has been similarly used as far as Mr. Dalton's area extends northward, *i.e.*, to Ancholme Head. To the north of Ancholme Head the breadth of the Lincolnshire Limestone becomes less, and so small a part of its surface lies to the east of the Roman Road, that the continuation of this method of description is no longer desirable. It is to the north of Ancholme Head that the variability of the Lincolnshire Limestone first assumes a stratigraphical significance, which in Sheet 86 on the north is so marked as to enable us to divide it into an Upper and Lower group.

Near Washingbrough Mr. Dalton assigns a thickness of about 65 feet to the Lincolnshire Limestone, it may attenuate from Lincoln northward, but the exposures toward the north margin of the map are too shallow and scattered to permit of a reliable estimate.

Mr. Dalton observes:—'The Lincolnshire Limestone is the only member of the Oolite series in these parts that exhibits oolitic structure, and it does so in great variety, ranging from a congeries of barely perceptible grains to what at first sight appears to be a conglomerate with pebbles reaching nearly an inch in length, but which prove to be merely calcareous concretions, similar in all but size to the granules of the normal oolite. Again, there is every gradation from a rock entirely oolitic to one which shows no such structure, the granules occurring more and more sparingly in the amorphous matrix. Within the area of drainage of the Witham, these lithological variations appear to have no stratigraphical value, the secondary action which has produced the oolitic structure having affected beds at every horizon throughout the mass, omitting portions here and there in an apparently capricious manner. In our present ignorance of the conditions favouring or retarding this structural change in originally amorphous rock, we can only speculate on the possible effect, on matter of varying porosity and charged with water of varying composition, of the pressure and corresponding rise of temperature to which, from independent evidence, we know that these beds have been subjected.

W. H. D.

In the area from Ancholme Head northwards, the Lincolnshire Limestone is not homogeneous, but it would be useless to draw boundary lines for the lithological variations displayed by the beds, although as we approach the northern margin of the Map, these lithological horizons fall more or less clearly into stratigraphical groups. In the survey of this area, lithological lines of demarcation were drawn, as far as practicable, with the view of ascertaining the lie and relative thicknesses of the component parts of the Lincolnshire Limestone, but it was found inexpedient to

transfer them for publication, as there is no strong contrast between the lithological varieties of the beds comparable with that displayed by the upper (Ponton) and lower (Kirton) beds of the Lincolnshire Limestone in Sheet 86, on the north.

The components of these lithological groups exhibit the following succession, subject of course to local variation, in the north part of Sheet 83.

Lincolnshire Limestone.	Grey limestones.	{ In many respects resembling the limestones of the Kirton Beds in Sheet 86.
	Semi-oolitic beds.	{ Whitish, cream-coloured, and buff limestones, with oolitic grains here and there. In their lower part these beds appear to be interstratified with nodular argil- laceous limestone, and hard, somewhat siliceous, limestone in places.
	Hydraulic Limestone series.	{ Hard grey limestones weathering brown. These beds probably represent the Hydraulic Lime- stone, and the beds above it, which are seen at Raventhorpe, in Low Santon road-cutting, and in the district between Winterton and Roxby (localities in Sheet 86).

The semi-oolitic beds appear to be in their upper part on the horizon of, probably, the lower beds of the Ponton Series in Sheet 86; the cream-coloured beds are often very like beds in the Ponton Series in the southern part of Sheet 86. The overlying grey limestones, which cannot be traced for more than a mile or two into Sheet 86, are either upon the horizon of the upper beds of the Ponton Series, or in its northerly attenuation this uppermost member of the Lincolnshire Limestone dies out.

The lower part of the semi-oolitic beds together with the Hydraulic Limestone series, may be said to occupy the same position as the Kirton Beds, nor is the passage of the one into the other remarkable, when we consider the impersistent character of the component loams, clays, and limestones in the typical Kirton Beds, and the development of coarse buff oolitic beds, and of arenaceous or siliceous limestones toward their base. The beds which we have called the Hydraulic Limestone series, ought of course, if that title were significant, to be embraced in the Basement Beds, but this cannot be done, as these beds, usually characterised by more dwarfed forms of life, have not been altogether included in the basement series in Sheet 86, but a distinctive hard bed at or near their base called the Hydraulic Limestone, was so taken, and that bed has not been detected in Sheet 83, although mention of beds of somewhat similar character will be found in the detailed notes.

Between Caenby Corner, Harpswell, and Hemswell, the semi-oolitic beds exhibit very indefinite characters, being in part composed of grey and buff arenaceous limestone, and in part of pale grey and whitish impure nodular limestone, in which the oolitic character is either absent or inappreciable. The hard beds seem to be interstratified with the more rubbly materials. These characters were exhibited in a quarry recently filled up, on the top of the hill above Hemswell, and by the high road near Harpswell, in the direction of Caenby Corner.

I. South of Lincoln.

The following notes are by Messrs. Penning and Dalton:—

The simplest method of describing the various sections of the Lincolnshire Limestone in the wide area south of Lincoln, will be to accept the arbitrary boundary furnished by the Lincoln and Sleaford high road, and take first the western and then the eastern parts of the area thus divided. Occasional seams and partings of calcareous shale, crowded with minute fossils, are seen in quarries and railway cuttings, but these never produce any feature beyond the limits of the sections exposing them, and cannot be traced with any certainty from section to section. A glance at the Map shows a series of villages along the escarpment of the Oolite, and a similar series on or near the less regular line of its outcrop, Branston being the only village not conforming to this rule, which arises from the all-important condition of water supply. That requisite of life is readily obtainable on either side of the tract of open porous limestone in which it is supported on the west by the impervious Lias clay, and on the east by the absence of means of escape, the rock being waterlogged up to the lip of overlying clay and overflowing in powerful springs.

FIG. 1.

Diagram-section of the Oolite plain south of Lincoln.

Villages.

Villages.



A. Lias.

B. Inferior Oolite.

C. Great Oolite Series.

D, D, D, Line of perennial saturation, with springs at points of intersection with surface.

W. H. D.

a. Western side of the Oolite plain.

An old quarry about a mile and a half east by north of Navenby shows 10 feet of fissile Oolite, and about a quarter of a mile north of this the following section is seen in another quarry:—

	Ft.
Rubbly limestone - - - - -	3
Grey clay - - - - -	1
Creamy oolitic limestone in five beds with thin clay partings - - - - -	6

East of the church at Boothby Graffo is a quarry showing several clay beds separating the beds of oolitic limestone, thus:—

	Ft.	In.
Rubbly limestone	-	5 0
Clay	-	0 6
Oolite	-	5 0
Clay	-	0 6
Oolite	-	1 6
Clay, thin irregular bed	-	—
Creamy limestone	-	1 6
Thick-bedded oolite	-	5 0

Eastward of Harmston Church the Oolite is raised in a quarry showing the following beds:—

	Ft.	In.
Rubble, passing down with undisturbed oolite	-	5 0
Shelly clay	-	0 6
Oolitic limestones	-	1 6
Creamy oolite with clay partings	-	6 0
Brown clay	-	0 2
Massive oolitic limestone	-	3 0

Half a mile north of this a shallow excavation shows, under three or four feet of rubble, two feet of hard, fine-grained, cream-coloured limestone underlaid by rock of the normal oolitic character.

A quarter of a mile north-east of Waddington a quarry shows the following divisions:—

	Ft.	In.
Rubbly limestone	-	6 to 8 0
White marly limestone, slightly oolitic	-	2 0
Grey clay	-	0 9
Marly limestone, slightly oolitic	-	1 0
Good oolite	-	5 0

A small exposure of thin-bedded limestone (the flakes averaging an inch through) was seen in 1878 half a mile west by south of St. John's Heath.

In a quarry a quarter of a mile south-east of Red Hall, Bracebridge, 4 feet of rubble overlies 7 feet of oolitic limestone in beds from 6 inches to a foot thick with partings, sometimes 3 inches in thickness, of shelly clay or shale.

W. H. P.

b. Eastern side of the Oolite plain.

Outside the village of Scopwick, on the north-west side, are some large quarries affording typical sections of the Lincolnshire Limestone, and the course of the fault, which here bounds the area of this rock, is easily traceable by the soil, clayey and with fragments of non-oolitic ragstone on the east, sandy with oolite fragments on the west.

W. H. D.

An old quarry about a mile west by north of Scopwick shows 10 feet of fine sandy false-bedded limestone under 5 or 6 feet of rubble. Half a mile to the west of this, coarse oolitic limestone, of a pinkish tint, is exposed in a quarry about 11 feet deep, of which rubble forms the upper 4 feet. The dip here is to east by north at 5°. North of Scopwick Lodge fine-grained slightly oolitic limestone is quarried to a depth of 10 feet under 4 feet of rubble.

In a quarry half a mile south-west of Blankney the limestones are worked to a depth of about 20 feet. The beds are somewhat thin and vary in texture from hard creamy stone, used in building, to soft rock only fit for lime. In another pit near by, at a lower level (now disused), the bottom beds are sandy limestone.

W. H. P.

The Oolite is seen under gravel half a mile south-east of Blankney Hall. Between this and Metheringham rise some fine springs.

W. H. D.

The following section is exposed in a quarry half a mile west of Metherringham:—

	Ft.	In.
Rainwash and rubble	-	5 0
Fissile, coarse, brown oolitic limestone	-	3 0
Massive whitish limestone	-	2 6
Blue limestone	-	1 0
Grey shale with ooliths	-	3 6
Hard oolitic limestone with <i>Nerinea</i> , &c.	-	4 0
Coarse brown sandy limestone	-	2 0

A quarter of a mile to the north-west of this a quarry on the south side of the road shows the following series of beds:—

	Ft.
Fissile limestones	4
Coarse yellowish sandy oolitic limestone	2
Very coarse false-bedded sandy oolite crowded with fossil shells, corals, &c.	2
Fine-grained sandy oolite in thin beds	8

A short distance south-west of Great Spring Head is a small quarry showing at the top some three feet of thin-bedded limestone of very typical oolitic structure; beneath this more sandy beds occur, passing down into coarser oolite.

The springs here issue in copious flow from fissures in fine-grained sandy limestone, the upper part of which is here and there of a pinkish-yellow tint.

A little south of Dunston Station a small quarry shows the following divisions:—

	Ft.	In.
Rubbly limestones	-	3 0
Marl with bands of chalky rock	-	2 6
Coarse oolitic, pinkish limestone	-	4 0
Marl with ooliths	-	1 6
Coarse oolitic limestone	-	2 0
Finer ditto	-	2 0

In a somewhat obscure section, about a mile and a half west of Dunston, the following beds are seen:—

	Ft.	In.
Chalky-looking limestone and rubble	-	—
Pink sandy limestone	-	0 6
Clay with chalky rock	-	2 0
Oolitic limestone	-	5 0
Grey clay	-	1 6
Oolitic limestone	-	—

Half a mile to the west of this a quarry by a farm shows about 16 feet of rock, as follows:—

	Ft.	In.
Rubbly limestone	-	2 0
Chalky limestone	-	1 0
White rubbly chalky limestone, with clay bands below	4	0
Fine oolitic limestone	-	1 6
Soft yellow creamy limestone	-	1 6
Marl	-	0 6
Hard thick-bedded oolitic limestone	-	6 0

W. H. P.

In the goods yard at Dunston Station a glaciated floor of limestone was laid bare under the Boulder Clay in 1882. This was partly quarried away and partly left with a protecting cover of Boulder Clay several inches thick, under the broken stone with which the yard is "metalled" in the neighbourhood of the goods shed. The rise of the rock surface to the west necessitated its being cut back, but the section thus formed presents no points of interest. Immediately north of the station, however, the line enters a very fine cutting, nearly 40 feet deep at one point, and showing at least four small faults which in general are very oblique to the faces of the section. At the north end of the

up (or eastern) platform is seen the base of the Upper Estuarine Series resting on the topmost beds of the limestone; the beds rise sharply to the north, and at 60 yards beyond the bridge (as measured along the centre of the railway) are thrown up 7 feet or more by a fault trending E. 2° S., and having southward at 60° to the horizon. There appears to be a second fault, with a north-easterly downthrow, running from where the first fault crosses the centre of the railway, in a direction S. 39° E. towards the station, disappearing from sight in the western span of the bridge. On the western or up-throw side of this is seen a bed of dark sandy bituminous and marly shale, rising northwards from the floor of the cutting to about 13 feet above it at the first fault, beyond which it is about 20 feet above the rails. Below this shale band are several minor partings, thus:—

						Ft.	In.
Limestone	-	-	-	-	-	15 to 20	0
Shale band	-	-	-	-	-	3	0
Limestone	-	-	-	-	-	6	0
Shale	-	-	-	-	-	0	3
Sandy limestone	-	-	-	-	-	6	0
Shale	-	-	-	-	-	0	3
Limestone	-	-	-	-	-	6	3
Shale	-	-	-	-	-	0	3

At 150 yards from the "first" fault is the third, trending E. 27° S., and, like the first, throwing up the beds to the northward. Nearly due west of Nocton Lodge a huge coral 6 feet in diameter displaces the regular bedding of the limestone next below the thick shale band (on the west side of the line), arching up the layers of rock that were deposited over it.

Here the section is:—

						Ft.	In.
Limestone, rubbly at top	-	-	-	-	-	15	0
Dark Shale	-	-	-	-	-	3	0
Limestone	-	-	-	-	-	6	0
Sand	-	-	-	-	-	0	3
Stone	-	-	-	-	-	0	6
Dark Shale	-	-	-	-	-	0	3
Limestone	-	-	-	-	-	6	0
Shale parting	-	-	-	-	-	—	—
Limestone	-	-	-	-	-	9	0
Shale parting	-	-	-	-	-	—	—
Limestone	-	-	-	-	-	—	—

About 16 chains north of this, a fourth fault, trending E. 40° S., throws down the beds 3 feet to the north, after which they run nearly horizontally to the end of the cutting.

The Lincolnshire Limestone is well exposed along the road from a quarter to half a mile west of Nocton Hall, and is worked in a small quarry to about 6 feet from the surface. The upper 2 feet is rubbly, below which is grey, blue-hearted, oolitic limestone. Immediately to the west of this, the road-cutting carried under the joint Great Eastern and Great Northern railway affords an interesting exposure of faulted limestone and shale. About 33 feet of rock, in beds varying from 6 to 18 inches in thickness, is seen on either side of the railway-bridge. 50 yards east of this, a large fault brings down beds altogether higher in the series, viz., the shale-band previously described, and several feet of the oolite overlying it. The amount of "throw" of this fault must be nearly 40 feet. 20 yards further east, a much smaller fault of 5 to 7 feet throw raises the shale-band to within a foot or so of the surface, reversing *pro tanto* the western fault. The direction of the latter is W. 28° N., and of the former, W. 30° N., but there are indications of a more complex faulting, thus, N, where the parallel lines indicate the plan of the main faults in the width of the roadway, and the oblique stroke, an intermediate fracture trending due west, and throwing down the shale on the south nearly to the level of the road. The hade of the intermediate or eastern fault at their junction is fully 45°. The shale-band at this point is 4 feet 6 inches in thickness, with two bands, two inches thick, of marly stone, about a foot from the top and bottom respectively.

W. H. D.

Half a mile north of Dunston Pillar we find exposed, in a small pit, the following beds :—

	Ft.	In.
Rubbly limestone	-	4 0
Hard grey rather creamy limestone	-	2 0
Grey clay, said to be about	-	1 6
Under this is more limestone.		

Three-quarters of a mile north of Nocton Grange a small quarry shows :—

	Ft.	In.
Rubbly limestone	-	3 to 4 0
Creamy-looking limestone	-	2 0
Pinkish thin-bedded oolite with clay partings	-	2 6
Coarser thick-bedded oolite	-	—

At the farm half-a-mile N.N.E. of Nocton Rise is a quarry showing the following beds :—

	Ft.	In.
Rubble	-	3 to 4 0
Fine oolite	-	4 6
Softer, sandy limestone	-	2 0
Hard coarse oolite	-	4 6

At the cross-roads about a mile west of Potter Hanworth, a small pit furnishes the following details :—

	Ft.	In.
Rubbly limestone	-	3
Coarse fissile oolite	-	2
Hard massive pinkish ditto	-	2
Hard blue shelly limestone	-	1
Grey clay	-	—

On the south-east of Branston Church, three quarries furnish, when taken together, the following section :—

	Ft.	In.
Rubbly limestone	-	3 0
White marly limestone	-	1 0
Marly clay	-	0 6
Cream-coloured oolitic limestone	-	2 0
Marl	-	0 4
White chalky stone, slightly oolitic	-	0 4
Marl	-	0 3
Oolitic limestone	-	7 0
Clay	-	0 2
Massive oolitic limestone	-	4 0
Clay band	-	0 2
Oolitic limestone	-	1 0

At about half-a-mile east of Branston Church is a quarry showing the following series :—

	Ft.	In.
Grey oolitic limestone	-	3 0
Coarse, brown, crumbling oolitic sand	-	0 to 0 6
Hard grey oolitic limestone	-	0 6
Hard grey limestone, not oolitic, very fossiliferous	-	2 0
Brown laminated clay	-	0 4
Creamy limestone	-	2 0

W. H. P.

And in another quarry near by, is seen :—

	Ft.	In.
Soil and rubble worked into remains of shale	-	5 0
Stone	-	2 6
Marly stone	-	0 6
Stone with irregular bands of fossiliferous shale	-	3 0
Shale	-	0 6
Hard, fine-grained, blue-hearted limestone	-	2 0

On the railway, a mile north-eastward of Branston, a cutting somewhat obscured by grass in its upper slopes shows the following beds :—

Marly shale, probably several feet thick.

Limestone - - - - - 6 ft. 6 in. to 8 ft.

Blue marly shale - - - - - 10 in. to 1 ft.

Limestone.

A quarter of a mile further north, the rise of the beds in that direction brings 13 feet of the lowest bed here named into view, to be speedily cut off, and thrown down out of sight by a fault of nearly 60 feet throw, trending E. 28° S.

W. H. D.

At some cottages about half a mile north-west of Branston Mill is a pit in marl with ooliths.

At a farm a mile and a quarter west of Branston, a small quarry shows 4 feet of rubbly limestone over 6 feet of good oolite, coarse-grained at top, finer below. Half a mile south-west of this, coarse oolite is quarried to a depth of 10 feet, the upper 3 feet being rubbly. Half-way between Branston and Canwick, a quarry, filled up in 1878, showed the following section :—

	Ft.	In.
Coarse rubbly oolitic limestone - - - - -	-	4 0
Clay - - - - -	-	0 4
Oolitic limestone - - - - -	-	0 6
Clay - - - - -	-	1 0
Oolitic limestones - - - - -	-	3 0

The cutting of the Great Eastern and Great Northern Joint Railway at Washingbrough affords a very fine section, extending from the Northampton Sand to very near the top of the Lincolnshire Limestone.

At the bridge, about a quarter of a mile south-west of Washingbrough Church, we have the following measurements (checked by the accounts of preliminary borings kindly furnished by Mr. Abbott) :—

	Ft.	In.
Rubbly limestone, soft and marly - - - - -	-	5 9
Solid limestone - - - - -	-	1 8
Hard clay and stony marl, fossiliferous - - - - -	-	4 10
Limestone, soft and marly in parts - - - - -	-	4 4
Hard marl and stony shale - - - - -	-	0 11
Limestone - - - - -	-	1 6
Marl - - - - -	-	0 3
Limestone - - - - -	-	0 5
Clay - - - - -	-	0 6
Limestone - - - - -	-	3 10
Marl - - - - -	-	0 7
Limestone - - - - -	-	18 4
Lower Estuarine Clay and Northampton Sand iron-stone as described on p. 39.		

At the cross-roads, half a mile to the south-east of this point, we get an additional thickness of 11 feet on the top, with a loss of 20 feet at the base, and the following section is presented :—

	Ft.	In.
Soil - - - - -	-	0 9
Loose stone and rubble - - - - -	-	6 6
Limestone, the last 20 inches blue - - - - -	-	10 9
Hard grey marly shale - - - - -	-	5 0
Limestone, blue above and below, yellow in middle - - - - -	-	6 9
Shale, black and yellow - - - - -	-	0 9
Limestone - - - - -	-	3 0

The beds dip but little more than the slope of the surface, and the thick shale band only passes below the level of the rails near the east end of the cutting. If 30 feet be taken as the thickness of limestone above this shale we have 65 feet as the entire thickness of the Lincolnshire Limestone.

The shale band is again seen in some old pits a quarter of a mile east of the church, where the following beds are exposed :—

Purplish sand with carbonaceous markings, 2 feet.

Thin band of ferruginous sandstone.

Yellow loam.

The limestone comes on just above.

Eastward of this is a quarry situated at the outcrop of the limestone from beneath the Upper Estuarine series, which, in a weathered, and possibly frost-moved state, is seen at the top of the section, consisting of the following beds :—

	Ft.	In.
Sandy loam, laminated in places	8	0
Broken limestone	2	0
Marly band	0	3
Thin-bedded oolitic limestone	6	0
Hard ferruginous sand	0	3
Tabular oolitic limestone	5	0

The dip attains an angle of 10° to N., 35° E.

In this pit is a large swallow hole 10 feet in diameter, over a fissure, lined by fine grey sand with lumps of ferruginous sandstone, the centre occupied by a gravelly mass of coarse sand, quartz pebbles, Oolite fossils, fibrous carbonate of lime, overlaid by a reddish-brown sand about a foot thick, and this by sandy wash. We have here first the Upper Estuarine beds, next a mixture of these with the relics of Drift, then, after the subsidence of these into the swallow hole, a wash down of the Estuarine beds over all.

A quarry, rather less than half a mile E.S.E. of Canwick Church, shows the following section :—

	Ft.
Rubble	2
Chalky limestone	1
Marly clay	1
Whitish oolitic limestone	2
Marly clay with bands of chalky limestone.	

On the north side of the road, about five furlongs east of Canwick Church, a small quarry shows the following :—

	Ft.	In.
Rubbly limestone	4	0
Regularly bedded limestone	2	0
Brown clay	0	6
Massive grey, blue-hearted oolite	5	0

At the north-west corner of the wilderness of old quarry-spoil, now planted and converted into a wood, a little to the south-east of Canwick, the lowest beds of the Oolite were seen in 1878 resting on ironstone of the Northampton Sand series. They consisted of thin-bedded flaggy limestone, of which 8 feet were seen.

W. H. P.

II. North of Lincoln.

Mr. Dalton writes as follows :—

In an account of the geology of Lincoln published in 1839* by Mr. W. Bedford, and subsequently, with the addition of map and section in 1843, a section is given ranging from the crest of the hill north of the Cathedral down to the river, compiled from various sources and containing some quaint references to fossils, &c. The author evidently supposed that the entire series of the Lower Oolite was represented, and misunderstanding the term Cornbrash, he took a bed of the Oolite (containing fossil shells,

* BEDFORD, W. *Mag. Nat. Hist.*, ser. 2, vol. iii., pp. 553-556 (1839), and *Papers Lincolnsh. Topogr. Soc.* for 1841-2, pp. 15-28, plates i., ii. (1843).

which seen in section, resemble, with a little stretch of imagination, the awns of barley) to be the Cornbrash of geologists, although from the close texture of the stone, he preferred the term Forest Marble. In the following transcript of his remarks, interpolations are given in square brackets [].

1. Alluvial Soil, from 6 to 10 inches in thickness.
2. Rubbly Stone; *Cardia* or Stone Cockles [and the *Maetra*] are profusely distributed here.
3. Called the *Blue* bed; a hard limestone wherein Spar and chrystalline Cockles [*Lucina bellona*] are found.
4. Knobbly or Boss Rubble; contains casts of shells.
A layer of Marle lies underneath.
5. The *Shell* bed; Stone Cockles in great variety are found in this bed.
A layer of Marle lies underneath.
6. The *Blue Limestone* bed; contains the *Maetra*, a species of the Muscle.
7. Three beds of the Grey Limestone, each bed intercepted with Marle; Oysters, Murex, the Lobster-tailed Nautilus or Miller's Thumb, the Chiton, and large Ammonites are found in these beds.
8. Three beds of fractured limestone, each bed intercepted with a layer of Marle.
9. A strong limestone bed called the Roof bed . . . mined . . . for building the Cathedral . . . to a great extent.
10. Three thin knobbly beds, intercepted with Marle.
11. The *Oolite Freestone* bed; Calc Spar occurs here in Rhombic and Prismatic crystals. Large Ammonites and the Terebratulid or Lapis Syringoides, and Fossil Wood are found in this bed.
12. The *Silver* bed; it abounds with Cornbrash and Archimedes Shells [*Nerinae*]; it is allied to the Forest Marble; . . . prismatic and rhomboid Calc Spar is found in this bed.
13. A bed of good building Stone, superior to the Silver bed, about 16 inches in thickness; this bed abounds with Cornbrash and Archimedes Shells. . . . Between the fissures, the Agaric mineral occurs in delicate opaque crystals. The Dagger Shells, Razor-sheath, and various other shells are found in this bed.
14. Two beds of good stone, with Oolite disseminated. In the first bed fossilized branches of trees sometimes occur, lying horizontally. Prismatic Calc Spar in bold crystals occurs in this bed. In the second bed the *Ostrea diluviana* is found.
15. The *Oolite* or *Roestone* bed is nearly 2 feet in thickness. . . . It is a hard Oolite, and becomes harder by exposure. . . . In some parts of this stratum it is *Blue-hearted*. . . . It will not burn into quicklime.
16. A bed of indurated Clay, 6 inches in thickness.
17. A bed of very hard Blue Stone.

A bed of very hard indurated Clay, 4 inches thick.

18. A thin bed of hard fine sandstone, firmly united to
19. The *Grey Oolite* bed, which is as firmly united to
20. The *White Oolite* bed. These three beds form one massive bed, nearly 4 feet in thickness.
A thin layer of clay, about an inch in thickness.
21. *Lower Oolite* bed . . . lies upon a bed of Yellow Ochry Earth, underneath which the springs begin to appear.
22. Ochry Ferruginous-stone bed [Northampton Sand].
23. *Ferruginous gravel* [Phosphate nodule bed] and *Sand* bed, underneath which, Pyrites in masses occur in some parts, just as we enter the
24. Thick bed of *Clunch Clay* [Upper Lias]. Ammonites, Nautili, and Belemnites occur in this bed. This clay shale is from 60 to 90 feet in thickness, and must be bored through into the heart of a rocky crust lying below, before water can be obtained.

25. *Ferruginous gravel* and *Sand* bed [Marlstone Rock-bed]; intervenes between the two beds of Clay, with nodules of Iron Pyrites.
 26. Thick bed of *Blue Clay shale* [Middle Lias clay], an excellent clay, when ground, for tiles and floor-bricks.

In this bed are three seams of rubbly Ironstone-clay, which dip towards the east, from 3 to 4 inches in thickness; the second seam is 2 feet below the first seam, and the third seam between 3 and 4 feet below the second. Fossilized Oysters, Muscles, and Periwinkles are found in this bed. See Mr. Foster's clay pits near the west common [now closed].

For like reasons to those given before, we shall divide the area of the Inferior Oolite by the Roman Road running north from Lincoln.

a. On, and westward of, the Roman Road.

On the east of the road, a mile and a quarter north of the Cathedral, a quarry measured by Mr. W. D. Carr gives the following:—

	Ft.	In.
Soil - - - - -	2	0
Yellow shelly oolite in three courses, <i>Pinna</i> , <i>Modiola</i> , and <i>Nerinea</i> abundant - - - - -	5	6
Yellow marly clay - - - - -	0	2
Hard yellow marly limestone with brown ooliths - - - - -	0	9
Yellow marly clay - - - - -	0	1
Semi-concretionary limestone - - - - -	0	5
Brown shale - - - - -	0	3
Impure earthy limestone, blue above, yellow below - - - - -	0	4
Blue shale - - - - -	0	2
Blue impure earthy limestone - - - - -	0	5
Blue shale - - - - -	0	2
Marly limestone - - - - -	1	5
Yellow shale - - - - -	0	1
Marly limestone - - - - -	0	8
Black and yellow shale - - - - -	0	2
Yellow limestone with brown ooliths - - - - -	0	11
Clay - - - - -	0	1
Fine-grained limestone, with many small <i>Gastropoda</i> ; not oolitic - - - - -	0	4
Clay - - - - -	0	1
Semi-concretionary marly limestone - - - - -	0	4
Black and yellow shale - - - - -	0	10
Coarse yellow limestone - - - - -	0	4
Coarse yellow shale - - - - -	0	4
Good shelly limestone - - - - -	0	8
Coarse yellow shale - - - - -	0	6
Yellow oolitic limestone, with <i>Montlivaltia</i> and shells - - - - -	1	5
Coarse yellow oolitic shale - - - - -	0	9
Fine-grained limestone, slightly oolitic, with a clay parting in the middle. Corals, wholly calcitized, occur above the parting, and <i>Pholadomya</i> in position of life below it - - - - -	3	10
	23	0

W. H. D.

A little to the north of the last, west of the road, a quarry shows:—

	Ft.	In.
Limestones with six-inch clay bands - - - - -	3	0
Limestone with clay partings - - - - -	3 to 4	0
Silty fossiliferous clay with nodules of blue lime- stone - - - - -	0	9
Creamy limestone - - - - -	4	0
Oolitic limestone, - - - - -		

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In the brickyard belonging to Messrs. Swan Bros. and Bourne on the North Cliff, the lowest beds of the Oolite are exposed on the brow of the clay pit, and those immediately above them in a small quarry a few yards in the rear.

W. H. D.

East of Burton Church is a quarry in fine-grained cream-coloured oolite.

On the Roman Road, due east of Burton, a quarry by the southern lodge shows :—

	Ft.	In.
Rubbly wash - - - - -	3	0
Limestone - - - - -	2	0
Brownish clay - - - - -	0	6
Creamy limestone - - - - -	0	9
Clay - - - - -	0	3
Fine-grained limestone - - - - -	5 to 6	0
Oolitic limestone.		

A little northwards of Riseholme are pits on both sides of the road, showing grey shaly clay, with fossils and a band of limestone nodules, separating the rubbly rock above from the bedded oolite below.

Half a mile east of South Carlton :—

	Ft.	In.
Brown loam - - - - -	3	0
Thin-bedded creamy oolite with clay partings	3	6
Thick-bedded oolitic ironstone - - - - -	2	0

By Watering Dyke House :— North of same :— West of road near by :—

	Ft.	Ft.	Ft.
Rubbly oolite - - - - -	1½	1¼	1
Thin-bedded coarse oolite - - - - -	2	3	3

North Carlton, 5 furlongs S.E. :— ½ mile E. :— 1 mile E. :—

	Ft.	Ft.	Ft.
Soil and rubbly oolite - - - - -	5	4	4
Thin-bedded oolite, with clay partings - - - - -	6	5	3

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The quarries near Scampton, Aisthorpe, Brattleby, Cammeringham, and Ingham Mill present similar sections to the above.

b. East of the Roman Road.

The railway cutting west of Greetwell traverses almost the entire thickness of the limestone, the uppermost beds of which, after passing under the Great Oolite series, are brought up again by a fault for a short distance, forming a narrow belt between the overlying beds on either side. The width of this belt measured along the railway is 175 yards, but the true width, at right angles to the boundary lines, is about 50 yards. The upper beds of the limestone are rubbly for 5 or 6 feet down, and then pass into massive thick-bedded oolite. No shale band is present in the exposed thickness of 30 feet.

W. H. D.

The western part of the cutting is much obscured by weathering, and only the stouter bands of rock project from the marly detritus. There appears to be a small fault, about 200 yards from the western end of the cutting, where the general sequence is as follows :—

	Ft.
Rubbly limestone and marl - - - - -	4-5
Oolitic limestone - - - - -	1
Rubbly oolite - - - - -	3
Oolitic limestone - - - - -	1
Grey clay, passing down into - - - - -	1
Yellowish sand with ironstone concretions - - - - -	1
Rubbly limestone - - - - -	6-7
Hard oolite - - - - -	1
Rubbly limestone.	

On the hill to the north of the cutting the Oolite has been proved by boring to a depth of 65 feet; but this may include overlying beds, and an allowance of 4 per cent. must be made for the dip, 14°.

In Mr. Kirk's quarry, east of the gaol, the ironstone of the Northampton Sand series has been reached in a well a little below the floor of the quarry. The visible section is as follows:—

	Ft.	In.
Rubbly limestone	-	6 0
Marl, with limestone nodules	-	2 0
Limestone in beds varying from 6 inches to 1 foot	-	6 0
Marl	-	0 6
Hard grey sandy limestone	-	3 0
Blue-hearted sandy limestone	-	4 6
Ferruginous sandy limestone.		

W. H. PENNING.

A similar series is exposed in the gaol quarry, and the same beds, with local differences, are worked on the Wragby Road, half a mile to the north, in a quarry showing the following particulars:—

	Ft.	In.
Soil	-	1 0
Rubbly stone	-	4 0
Marl, with limestone concretions	-	1 2
Rubbly stone	-	2 0
Good limestone	-	7 0
Shale	-	0 4
Stone	-	2 7
Stone	-	1 6
Shale	-	0 2
Stone	-	1 4
Stone	-	1 0
Ferruginous sandy stone.		

To the eastward of the fault, in the neighbourhood of Bunker's Hill, are four small pits in the Oolite, two on either side of the road. Those on the north of the road are in different horizons, in consequence of the dip, the top-most beds in the western passing below the floor of the eastern quarry. The same is the case with the openings south of the road, the nearer of the two being in higher beds than the further. The dip here is a little higher than usual, being fully 5° towards the E.N.E., and a small fault with a W.N.W. trend, and a northerly downthrow of 3 or 4 feet traverses the hole dug for a limekiln in the northernmost of the two southern pits.

On the Nettleham Road, rather more than half a mile from the Cathedral, a small quarry now abandoned shows, under 5 feet of rubble, a band of fossiliferous shaly marl nearly 3 feet thick overlying 6 feet of limestone. Immediately to the east of this is a fine series of quarries above 100 yards in length, and ranging in depths varying from 20 to 30 feet. The beds exposed in these are below the thick marl band last referred to, relics of which used to be seen at the west end of the larger excavation, blending with the soil and rubble on the top of the workable stone. The extension and deepening of this part of the quarry in 1884 has destroyed these traces, giving instead a much more complete section of the lower beds behind the roadside cottages, the following measurements of which are kindly furnished by Mr. W. D. Carr:—

	Ft.	In.
1. Vegetable soil	-	1 5
2. Rubbly oolite	-	2 9
3. Semi-crystalline shelly limestone	-	2 5
4. Irregular shale band	-	0 1
5. Fine shelly limestone	-	0 6
6. Yellow marl, with irregular band of limestone	-	0 5
7. Fine-grained limestone, irregularly oolitic	-	0 9
8. Yellow marly oolitic shale	-	0 5
9. Good shelly limestone	-	1 6
10. Coarse earthy shale	-	0 5

	Ft.	In.
11. Coarse blue limestone	0	7
12. Dark coarse shale, with indurated band in centre	1	2
13. Fine marly limestone of splintery fracture	1	5
14. Clay	0	2
15. Limestone as No. 13	0	6
16. Yellow clay	0	1
17. Fine-grained limestone	0	2
18. Yellow marl	0	1
19. Fine limestone, irregularly oolitic	0	10
20. Yellow marl	0	1
21. Limestone as No. 19	0	5
22. Yellow marl	0	1
23. Limestone as No. 19	1	5
24. Laminated coarse yellow shale	0	1
25. Limestone as No. 19	0	4
26. Shale as No. 24	0	4
27. Very fine-grained marly limestone of splintery fracture	0	6
28. Blue clay	0	1
29. Limestone as No. 27	0	7
30. Yellow clay and hard marl	0	5
31. Fine shelly limestone	4	10
32. Irregularly oolitic yellow limestone	2	9
33. Yellow clay	0	3
34. Yellow shelly oolite, blue-hearted	1	7
	<hr/> 29	<hr/> 5

Further back from the road, and accessible by a deep-cut lane from the N.E. end of the cottages, is another quarry, the base of which in wet seasons is often several feet deep in water, whilst the vertical sides render the upper beds difficult of examination. As the beds differ somewhat in thickness and character from the above section, we subjoin Mr. Carr's measurements, with the corresponding numbers of the first section in square brackets for the purpose of correlation.

	Ft.	In.
1. Vegetable soil	1	8
2. Oolitic rubble	4	4
3. Yellow limestone	[7]	1 4
4. Limestone and shale	[8]	0 8
5. Yellow limestone	[9]	1 0
6. Reddish oolitic shale	[10]	0 4
7. Bluish-grey limestone, coarse at base	[11]	1 8
8. Blackish-grey shale	[12]	0 3
9. Coarse dark limestone, ooliths elliptical, flattened		0 8
10. Red clay shale, with similar ooliths		0 4
11. Fine limestone irregularly oolitic, of splintery fracture	[13-15]	1 3
12. Shale	[16]	0 1
13. Limestone as No. 11	[17]	0 4
14. Clay	[18]	0 1
15. Limestone as No. 11	[19]	0 7
16. Marl with limestone nodules	[20-22]	0 6
17. Shelly oolitic limestone	[23]	1 7
18. Yellow marl	[24]	0 1
19. Fine-grained limestone	[25]	0 5
20. Yellow shale	[26]	0 3
21. Good limestone, irregularly oolitic	[27]	0 4
22. Yellow clay	[28]	0 1
23. Limestone as No. 21	[29]	0 7

						Ft.	In.
24.	Yellow clay, with a band of hard marl	-	[30]			0	5
25.	Yellow shelly limestone	-	-			1	0
26.	Irregularly-oolitic limestone	-	-	[31]	{	3	9
27.	Yellow limestone	-	-	[32]		1	1
						24	8

The following section is furnished by a quarry a mile and a quarter north-east of Lincoln Cathedral :—

						Ft.	In.
	Rubbly oolitic limestone	-	-	-		3	0
	Bedded cream-coloured limestone	-	-	-		2	0
	Hard brown calcareous clay	-	-	-		0	6
	Hard oolitic limestone	-	-	-		2	0
	Very hard fossiliferous oolite, blue internally, but weathering nearly white	-	-	-		2	0

A pit close by, on the north of the road, and at a slightly lower horizon shows very oolitic limestone in thin layers, with lines of current bedding.

Six hundred yards beyond this, a hard fossiliferous limestone is quarried, in one bed 4 feet thick, which rests on soft sandy limestone, and is overlaid by 6 feet of thin-bedded soft oolite. The lower part of the thick bed is blue, the upper part cream coloured.

A quarter of a mile N.N.E. of this, another quarry shows 12 feet of coarse oolite, in beds varying from 6 to 18 inches in thickness, underlaid by fine-grained creamy limestone, of which about a foot is exposed.

To the N.N.W. of the last section is another small quarry by the farm to the west of the road. Half a mile westward of Nettleham are two very large quarries in the uppermost beds of the limestone, presenting few characters not seen elsewhere. In the floor of the more southern of these, are large corals wholly converted internally to calcite, and only proved to be of organic origin by their surface, which when developed by weathering or acid shows the calices, septa, &c. of the *Isastræa* and *Montlivaltia* very distinctly. Dilute sulphuric acid is the best for this purpose, as it readily attacks the non-crystalline matrix, leaving the fossil unharmed.

Another quarry opposite the road to Riseholme, and at about the same horizon as the last named, yields *Nerinea* in great abundance.

Other quarries not meriting more than the bare mention of their position, are to be found in the following places :—

Half-a-mile S.S.W. of Friezeland.

A furlong north-west of Friezeland.

Three furlongs west of Dunholme Lodge.

A quarter of a mile north-west of Old Man's Head Spring.

A mile and a quarter west of the same spring.

A quarter of a mile north-east of the last quarry.

Half a mile west of Hackthorn Gorse Cover.

South of Hackthorn Hall Park.

Three-quarters of a mile W. by S. of West Firsby.

W. H. D.

We may preface the following detailed notes on the Lincolnshire Limestone north of Ancholme Head by a sketch of the positions of its lithological components referred to in the introductory notes. (*See pp. 43, 44.*)

The upper or grey limestone series makes a very irregular boundary with the semi-oolitic beds below it, projecting westward on the high ground, deflecting eastward up the valleys. This boundary, at best a rough one, from Ancholme Head to the second *t* of the word Glentworth on the Map, runs near to the Ermine Street on either side of Fillingham Castle Lodge; from the *t*

of Glentworth to Spital Plantation, Glentworth Dog Kennel being within it; from Spital Plantation to Old Leas, projecting westward from Spital Plantation, and from Old Leas toward Willoughton Mill; from Old Leas toward the Roman Road at the 14th milestone, and thence northward into Sheet 86. Between Old Leas and Blyborough Mill a patch of grey limestone occurs as an outlier, also a long patch south of Willoughton Mill.

The upper boundary of what we have called the Hydraulic Limestone series is most indefinite; as far north as Willoughton Mill it seems to run close to the crest of the Oolitic escarpment, but from Willoughton Mill northward two lines may be drawn for it; one for the Hydraulic Limestone (which may be present) near the escarpment; the other, from Willoughton Mill to Blyborough Mill, which is probably not a stratigraphical line, might be prolonged into Sheet 86 to join the boundary between the Ponton and Kirton Beds.

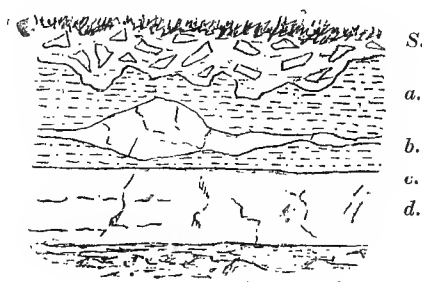
At Ancholme Head a quarry shows about 10 feet of cream-coloured partially oolitic rock; the overlying beds would appear by surface evidence to consist of grey limestones associated with cream-coloured and oolitic limestone, so that here there may be said to be no lithological horizons in the Lincolnshire Limestone.

Just below the Upper Estuarine Beds at a mile to the north of Ancholme Head very oolitic rock was exposed in a drain.

West of the 10th milestone on Ermine Street, a quarry excavated for road and wall stone affords the following section:—

FIG. 2.

Quarry west of Ermine Street.



Vertical scale, 1 inch = 8 feet.

FT. IN.

S. Brown soil with fragments of grey limestone of irregular thickness.

a. Light drab loam - - - - - About 3 0

b. Tough irregular impure limestone - - - 1 inch to 0 4

c. Half consolidated drab loam (? decomposed limestone) - - - - - 0 10

d. Hard grey limestone, splitting in places into 3 beds About 3 0

(b) is lenticular, in one part of the quarry it develops into an irregular boss of hard grey shelly limestone, considerably reducing the thickness of (a) and almost cutting out (c). The beds have a general easterly dip of about $1^{\circ} 30'$.

In the plantation opposite the turning to Glentworth a hard even bed of limestone is visible at 6 to 7 feet from the surface in one of several disused pits, which nowhere afford exposures of more than from 2 to 3 feet. The limestone, which might represent the Hydraulic Limestone, contains small fossils; it is overlain by about a foot of similar rock, more broken, both weathering to a cream colour; above this, whitish brashy stone is visible. The hard limestone, which may be one bed broken irregularly by lateral joints, is exposed near the bottom of the pit to a depth of 18 inches. If it were the Hydraulic Limestone, it would scarcely make a perceptible difference in the boundary we have drawn for the Basement Beds.

Between the plantation and the high road near Harpswell, a quarry shows two or three beds of hard, tolerably even, limestone, possibly representing the Hydraulic Limestone, at 6 to 7 feet from the surface, under whitish and buff rubble (brashy limestones much decomposed P). In the part of the quarry now worked 5 feet of hard limestone was exposed. There are appearances of small faults in the quarry, cracks filled with earthy matter, five in number, apparently running in north-westerly and south-easterly directions.

By the high road, north of the letter *p* in the word Harpswell, a quarry shows the following section :—

			Ft.	In.	Ft.	In.
Brown soil upon stony rubble	-	-	3	0 to 6	0	
Tough, somewhat arenaceous, uneven limestones	-	-	1	0 to 3	0	
Buff brown loamy band from	-	-	0	6 to 0	8	
Irregular soft whitish broken limestones, decomposed and shaly in places, exposed to a depth of from	-	-	2	0 to 3	0	

Eastward of the above, at the turning to Glentworth Dog Kennel, cream-coloured beds, partially oolitic, are exposed in a quarry.

Grey limestones are exposed in the following places :—near Glentworth Dog Kennel, on south-east; near an exposure of Upper Estuarine Beds east of Caenby Hall; in quarries on either side of the road to Gainsboro', near the Cross-roads (Caenby Corner) south of Spital; on the south side of the road to Glenthams, at about a quarter of a mile from Caenby Corner; by the road south of the little Church at Spital. Pale grey limestones are shown in a small quarry on the south side of the stream on the east of Ermine Street at Spital.

In all the above mentioned, after Glentworth Dog Kennel, the limestone exposed is very little, if not immediately, beneath the Upper Estuarine beds.

On the west side of the large farm enclosure on the Map, by the road from Hemswell toward Norton Place, at rather more than half a mile from Ermine Street, a quarry shows grey limestones, more or less fossiliferous, containing corals, for the most part occurring in tolerably large irregular slabs, but in places apparently degenerating into broken shaly matter.

The section in descending sequence is as follows :—

								Ft. In.	Ft. In.
Brown soil	-	-	-	-	-	-	-	1	0
Pale grey loamy clay	-	-	-	-	-	-	-	1	0
Limestone	-	-	-	-	-	-	-	0	6
Irregular parting of grey loam with broken limestone at base	-	-	-	-	-	-	0	6 to 0	9
Limestone	-	-	-	-	-	-	0	9 to 0	10
Impersistent or very thin, shaly parting	-	-	-	-	-	-	0	2 to 0	6
Limestone to base of exposure, about	-	-	-	-	-	-	-	1	6

The dip appears to be easterly at about 1°. At about a quarter of a mile north of the path-road from Hemswell to Norton Place, and about a mile west from the Ermine Street, a small quarry shows rubbly rock, partially oolitic, 2 feet 6 inches thick, upon pale grey and cream-coloured tough rock, with oolitic grains dispersed through it in patches, exposed to a depth of from 2 to 3 feet.

At a large farm enclosure, shown on the Map, 70 chains distant from Hemswell Church in a direction E. 29° N., beds resembling chalk in jointing and general appearance, and apparently horizontal, are exposed in a quarry.

The following is the detailed section from the surface downward.

	Ft.	In.	Ft.	In.
Broken limestone in light brown soil - - -			2	0
Whitish rubbly limestone and soil - - -			1	0
Drab loamy clay seam - - -	0	3 to 0	4	
Whitish broken argillaceous limestone, about -			0	6
Drab brown loamy clay, about - - -	0	2 to 0	3	
Tough unweathered greyish-white earthy limestone in two or three beds - - -	0	9 to 0	10	
Pale brownish and drab loam - - -	0	7 to 0	9	
Cream-coloured limestones, with regular oolitic grains irregularly dispersed throughout, exposed to a depth of about - - -			4	0

By the small farm on the map south of the road to Willoughton Mill, south of Old Leas, about 4 feet of rubbly grey limestones are exposed by a pond.

By the road on top of the escarpment at about half a mile to the south of Willoughton Mill, a quarry shows beds below the above, and probably near the base of the Lincolnshire Limestone; the descending sequence is as follows:—

	Ft.	In.	Ft.	In.
Brown soil -	1	0 to 3	0	
Pale yellowish brown, cream-coloured, and grey loamy clay with fragments of whitish and grey earthy limestone - - -	2	0 to 3	0	
a. Tough grey earthy limestone -			0	6
b. Very hard tolerably regular grey limestone -	0	10 to 1	0	
c. Hard grey limestone - - -	0	6 to 0	7	
d. Hard grey limestone weathering pale brown, partly oolitic, fracture very uneven -			0	4
e. Very hard grey limestones, fracture in places tolerably even, bedding planes apparently impersistent, one bed a foot thick, splitting into 3 or 4 beds - - -			2	6

The limestones dip in an easterly direction at about 2° in one place, and are horizontal in another; (e) may represent the Hydraulic Limestone, and from (a) downward, the beds might be called the Hydraulic Limestone series. These beds are also exposed in a quarry at Willoughton Mill, and in drains north-east of Willoughton Mill, W.N.W. of Old Leas.

The same beds appear to have been cut through by the Blyborough mill-stream, which shows:—

	Ft.	In.
Brown soil and grey and brownish loam and clay -	5	0
Tough grey limestone splitting laterally into irregular pieces - - -	2	0
Hard compact limestones - - -	3	0

The lower beds here are similar in character to what has been in Sheet 86 mapped as Hydraulic Limestone, and are probably a continuation of the beds marked (e) in the quarry half a mile south of Willoughton Mill.

A short distance west of the words Old Mill on the Map, cream-coloured and buff, partially oolitic, rock is shown for about 3 feet through the grass at the bottom of a disused quarry, which once no doubt displayed the overlying grey limestones indicated by surface stones in the vicinity.

In a ditch nearly a mile south from Blyborough Mill, beds of grey limestone are exposed to a depth of about 5 feet; they appear to be the upper beds of the Lincolnshire Limestone.

At a mile and a quarter due south from Blyborough Mill a quarry exhibits the following section of beds, in descending sequence:—

	Ft.	In.	Ft.	In.
Soil - - -			0	6
Limestone rubble in brownish loamy clay - -			1	6
Brown loam (apparently resulting from the decomposition of rather oolitic limestone) - -	0	3 to 0	4	
Broken grey limestone with oolitic grains, from -	0	10 to 1	0	

	Ft.	In.	Ft.	In.
Tough grey limestone in two beds	- {		0	9
Seam of drab and grey clay - - -	-	0	2 to 0	4
Irregular grey limestone - - -	-	0	2 to 0	6
Grey and drab loam, from - - -	-	0	6 to 1	0

The bottom of the quarry is formed by about 6 inches of grey limestone containing irregular oolitic grains.

An adjacent pit shows about 2 feet of grey limestone with a shaly parting, apparently dipping eastward at 1°.

At the turning from the Ermine Street to Atterby an old quarry shows the following section; beds given in descending order :—

	Ft.	In.
Grey limestone with numerous fossils, chiefly corals in the form of calcite, about - -	-	1 0
Pale brownish loam, about - -	-	0 3
Rather earthy limestone, about - -	-	0 3
Pale brownish loam, about - - -	-	0 10
Tough, rather even, grey limestone with large irregular oolitic grains, about - -	-	0 4
Pale brown loam, about - - -	-	0 6
Limestone at the bottom of the quarry.		

An adjacent quarry shows the uppermost bed which has been partly removed from the surface in the old quarry. Its thickness under a heading of stone and loam is from 2 to 3 feet. At about half a mile to the south, on the east of the Ermine Street, this coralline limestone, or a bed much resembling it, is exposed at the surface in two shallow quarries.

At Atterby mill from the absence of clear sections the junction between the Lincolnshire Limestone and Upper Estuarine Series is very indefinite, we have been guided by feature as well as by the principle of giving preference to the older rock in doubtful cases in drawing the boundary, but it should be mentioned that the version adopted entails an abnormal representation of the top of the Lincolnshire Limestone, as will be seen from the following :—

At the turning to Atterby mill, in the roadside ditch, shaly arenaceous and ferruginous grey and brown beds are partially exposed; limestones may occur in irregular lenticular patches in them: If these beds are Upper Estuarine the base of that series would cross the road to the Ermine Street at about 10 chains west of the position we have adopted for it, and from this point to the Ermine Street at about half-way between the twelfth and thirteenth milestones on the Map, the boundary would have to be taken about 5 chains lower.

By the road from Snitterby to the Ermine Street, on the east of the stream, an old quarry shows the uppermost beds of the Lincolnshire Limestone, consisting of irregular, tough, rubbly, grey fossiliferous limestone, probably intercalated with loamy material, and overlying more even grey limestones.

On the west of the stream, hard beds of compact grey limestone, with patches of oolitic grains, are shown in shallow stone pits: one of these is parallel to the road and exhibits more than a foot of the hard limestone under about a foot of brashy stone capped by soil; the beds in this long pit conform with the surface slope. Further west, near the Ermine Street, excavations by the road furnish a long continuous exposure of hard compact limestone (most probably the same bed) to a depth of about 18 inches.

Near the windmill north of Blyborough Mill, at the northern margin of Sheet 83, a quarry displays the following descending sequence :—

	Ft.	In.
Brown soil - - - -	-	1 0
Broken stone (pale grey and cream-coloured, partly oolitic) in brownish soil - - -	-	3 0
Rather tough pale grey earthy limestone with oolitic grains dispersed throughout, split up by irregular lateral joints, quarrying out sometimes in rather large pieces - - -	-	from 1 to 3 0

The beds have a very slight easterly inclination.

CHAPTER VIII.*

THE LOWER OOLITES—*continued.*

THE GREAT OOLITE SERIES.

The Upper Estuarine Series.

The Upper Estuarine beds occur normally upon the outcrop slope of the escarpment feature made by the Great Oolite Limestone; but, through the removal by denudation of the lower beds of the Great Oolite Limestone, their outcrop attains a greater breadth in places, and exhibits a surface diversified by features resulting from the unequal wearing of the irregularly associated sands and clays of which they are composed.

On the south of the Witham Valley and on its northern border, the Upper Estuarine beds are faulted against the Lincolnshire Limestone, in the following places:—between Scopwick and Blankney; on the west of Nocton; south-west and south of Heighington; at Greetwell. Near Potter Hanworth and Nocton they are concealed by Boulder Clay, and near Blankney and Metherringham by gravels.

North of the Witham Valley, except at Greetwell, the Upper Estuarine beds appear to be quite undisturbed by faults and are very seldom concealed by Drift.

The thickness of about 35 feet, assigned by Mr. Dalton to these beds in the Lincoln district, decreases as they are traced northward, and would not appear to exceed from 15 to 20 feet in the area north of Ancholme Head.

In the Sudbrook Holme well section the following are no doubt referable to the Upper Estuarine Series, and give the total thickness of that division:—

			FT.	IN.	FT.	IN.
Green clay	-	-	-	3 8	}	24 0
Stone	-	-	-	5 4		
Clay	-	-	-	15 0		

Mr. Dalton writes of these beds as follows:—

The Upper Estuarine Series consists of sands and sandy clays about 35 feet in thickness. There are few fossils, except in the oyster beds near the upper limit of the division, but the lower part is shown to be of fluviatile origin by the occurrence of *Paludina*, &c. in the clays penetrated by a well at Potter Hanworth Station.

W. H. D.

The following notes on the southern part of the area are by Messrs. Penning and Dalton:—

The Upper Estuarine clays are seen in ditch-sections between Scopwick and Blankney, and were penetrated, from near the top to the Inferior Oolite, at a depth of 25 feet, in a well half a mile east by south of Blankney Hall.

W. H. PENNING.

* Written, except where otherwise noted, by Mr. W. A. E. Ussher.

East of Dunston station the Upper Estuarine clays and Great Oolite Limestone are exposed in deep ditches under the Boulder Clay, and they have been traced, by similar evidence, to the fault near Potter Hanworth, which is proved by their sudden projection to the west of their previous outcrop.

In the well at Potter Hanworth Station the lower part was found to consist of blue and green clay, with masses of jet and bands of pyritous sandstone, in which occur remains of Fishes, Entomostraca, and *Paludine*.

Water is obtained from "rock" at a depth of 49 feet from the level of the platform; but, as this is probably the hard sand base of the Upper Estuarine Series, 12 or 14 feet above the Inferior Oolite, and as the Great Oolite Limestone is seen in the road, at about 70 yards to the south, and at 18 feet lower level, there is probably a considerable depth of Boulder Clay in the 49 feet, replacing the Great Oolite (boulders of which it contains), and some of the subjacent clays (out of which its bulk is apparently formed). Traces of blue clay are seen under the Boulder Clay at the further end of the cutting northward from the Station.

The next cutting, opposite Longhills, traverses the upper beds of this series, but affords no clear section. The ditches on the flanks of the little valley to the north occasionally give a glimpse of the upper clayey beds.

This series is admirably exposed, to nearly its full thickness, in the railway cutting at Heighington. The beds lie in a slight synclinal, and to the eastward abut against a faulted face of the Inferior Oolite. Their natural junction with that rock is marked by a feature crossing the line at the Station, and below the level of the rails. The cutting shows the following sequence:—

	Fr.	1n.
Great Oolite Limestone	-	11 0
Shales with three hard sandy bands, 6 to 12 inches thick, full of <i>Ostrea</i>	-	7 7
Tea-green shales	-	3 5
Ochrey shale	-	3 6
Green shale	-	4 6
Ochrey shale	-	2 6
Grey shale	-	6 3
White sand, about 14 feet, but seen to depth of	8	0

W. H. D.

At the east end of Heighington the Upper Estuarine beds are seen in a roadside ditch, and an overgrown pit close by was doubtless dug in them. Rock is said to have been met with at the top and bottom, the clays being 20 feet thick. The "rock" at the top was probably one of the oyster beds.

A few yards from the angle of the road eastward of Greetwell Church is an old clay pit, in which the following beds are exposed:—

	Fr.
Grey shaly clay	3
Yellowish clayey sand	1
Grey shaly clay with hard calcareous nodules	4

W. H. P.

The series is twice traversed in its full thickness by the railway cutting, but the sections are now much obscured by weathering, though the acidity of the soil from decomposing pyrites makes the vegetation coarse and scanty. The following appears to be the sequence of the several beds:—

	Fr.
Great Oolite Limestone passing down into greyish-blue clay, weathering yellow, with <i>Rhynchonella</i> , <i>Ostrea</i> , &c.	14
Hard sand of a pale mauve tint	1½
Blue clay weathering yellow and brown	6
Hard sand, pale mauve, with carbonaceous plant-markings	9
Line of nodular hæmatite and limonite with veins of fibrous gypsum, resting on the Oolitic Limestone (Inferior Oolite).	

The ironstone band at the base is referred to by Professor Judd* as invariably present at the junction of the sands with the Inferior Oolite. It is probably due to such recent chemical action as:—the oxidation of iron pyrites

* Geology of Rutland, p. 189.

by percolation of atmospheric water, the reaction of the ferric sulphate on the carbonate of lime, and the further oxidation of the carbonate of iron to peroxide. The sulphate of lime forms veins of fibrous gypsum in the junction bed.

Northward from this point the clays are rarely exposed, except in ditch-sections: they occupy a steep slope between the plain of Inferior Oolite, on the west, and the slight but continuous escarpment of the Great Oolite Limestone.

The upper beds of the Upper Estuarine Series and the overlying Great Oolite Limestones were exposed in draining, north of Nettleham.

In a singular projecting spur of the Upper Estuarine clays rising above a plain of Inferior Oolite, a quarter of a mile south-east of Dunholme Lodge, the plough turns up very stiff green and blue clay.

In the neighbourhood of the Gorse Cover, between Welton and Hackthorn, draining operations, in 1883, showed the clays at several points, not easy of verbal mention from the paucity of topographical indications on the Map. All the deeper ditches in the tract mapped as Upper Estuarine beds, and some of those on the western edge of the Great Oolite Limestone, show, when freshly cleaned, the blue or yellow clay into which they have been dug.

West of Spridlington, the bridle-road between Hackthorn and West Firshy shows the Upper Estuarine clays, which were also turned up by the plough near the road west of Saxhy.

W. H. D.

The Upper Estuarine series, in the north part of Sheet 83, appears to be largely composed of sand, irregularly associated with clay, either constituent locally prevailing: this would account for soils, much resembling Blown sand, near Caenby Hall and other places in the vicinity of which Upper Estuarine beds are known to occur.

In the stream on the east side of West Firshy dark grey clays of the Upper Estuarine Series are shown, for about 10 chains, under Great Oolite Limestone.

Green clay is exposed in the Upper Estuarine beds at three-quarters of a mile south of Normanby Cliff Farms. For a mile and a half south from these Farms, the Upper Estuarine beds form a thin band on the steep slope below the Great Oolite Limestone.

At half a mile east of Caenby Hall Upper Estuarine clay is exposed in a drain under Great Oolite rock; it is also exposed by ponds, near Low Walk Wood; by Caenby Hall Garden wall; and at 30 chains, E. 35° N., from Caenby Hall. Sand is exposed in a pit near Caenby Hall, close to a quarry in Lincolnshire Limestone.

On the south of Low Walk Wood the Upper Estuarine beds are to a great extent concealed by Boulder Clay.

Between Fox Cover and Spital and Caenby Corner, the mode of occurrence of the Upper Estuarine beds is somewhat abnormal, for their junction with the Great Oolite Limestone above is scarcely defined by feature, but the sands in their lower portion make a marked feature at their junction with the Lincolnshire Limestone. Probably owing to the irregular association of their component sands and clays, the surface occupied by the Upper Estuarine beds here presents a ridgy, broken character.

Near the letter S of the word Street, in the words Spital on the Street on the Map, whitish sand, weathering brownish, is shown.

In a ditch by the Ermine Street, at from 3 to 4 chains south of Norton Place Lodge gates, bluish grey and greenish clay is exposed, and below it consolidated beds of sand are shown. From this we may infer that the Upper Estuarine Series about Norton Place is largely composed of sand, the soil partly derived therefrom in places concealing its junction with the Lincolnshire Limestone.

In the ditch by the turning to Atterby Mill dark grey clay is exposed; from its position it ought to belong to the Lincolnshire Limestone, as it occurs on the dip slope of that formation, near the spot where it should pass under the Upper Estuarine Series.

About Atterby, on the north-east, south-east, south, and south-west, the Upper Estuarine beds are not clearly indicated. Ditches on the slopes, at 3 to 5 feet from the surface, expose whitish cohesive sand or loam, and dull drab and yellowish-brown sand. The pit by the road west of Atterby shows very stiff clay, which is exposed also by the road west of Atterby.

After considerable hesitation I have come to the conclusion that, here, the uppermost beds of the Lincolnshire Limestone consist of an irregular association of clay and broken sandy shale with limestone, and that the Upper Estuarine Series is principally composed of clay. (See p. 61.)

The Great Oolite rock terminates just west of Atterby houses.

For some distance north of Atterby, probably owing to the occurrence of very stiff clay as well as sand in the Upper Estuarine Series, the ploughed soil might almost be taken as an indication of Boulder Clay; but, as we proceed northward indications of the beds above and below are sufficiently clear to render the boundaries of the Upper Estuarine Series nearly certain.

On the north side of the Snitterby valley at the margin of Sheet 83, below the Great Oolite Limestone boundary, the Upper Estuarine sands form a small mound or hill, which may be capped by a minute outlier of Great Oolite Limestone, but, if so, it is too insignificant to show on the Map.

Great Oolite Limestone.

Like the Upper Estuarine Series, the Great Oolite Limestone at Greetwell and south of the Witham valley is partially concealed by superficial deposits and affected by faults, whilst to the north of the Witham valley its superficial continuity is unbroken, and its dip slope seldom partially obscured by Drift.

Speaking of the southern part of the area, Mr. Dalton says:—

The Great Oolite Limestone is a compact shelly ragstone, used for road metal and rough walling; its average thickness is 15 feet.

Ditch and railway sections are the only exposures of the Great Oolite Limestone within the drainage area of the Witham, It is quarried for road metal west of Saxby, but south of this, though blocks picked off the fields, or raised in draining, are used as rough building stone, or to repair roads, none is dug primarily for these purposes.

W. H. D.

West of Saxby, Owmbly, and Normanby, the Great Oolite Limestone forms a rock of some economic importance, furnishing tolerably thick beds, suitable for building purposes; but the general tendency of the rock to split along lateral joints, or what might be called irregular incipient bedding planes, is apparent even in parts of the best stone-beds. As we proceed northward the Great Oolite Limestone becomes more brashy, and there are beds in it so like Cornbrash that a very detailed investigation was necessary to prove that the Cornbrash was absolutely nowhere in contact with the Great Oolite Limestone.

In the Sudbrook Holme well section, beneath two beds of clay, (11 feet 6 inches and 14 feet thick, respectively) representing the Great Oolite Clays, the following beds evidently belong to the Great Oolite Limestone:—

	FT.	INS.	FT.	INS.
Stone	-	4	0	} 19 6
Clay -	-	1	0	
Shell-rock -	-	14	6	

As the Great Oolite Limestones pass out in Sheet 86, apparently interdigitating with clays, and finally permitting of the direct superposition of the Great Oolite Clay upon the Upper Estuarine Series, the association of clay bands, as in the well, with the limestones of the Great Oolite is only to be expected.

Mr. Dalton furnishes the following observations :—

Between Scopwick and Blankney the Great Oolite Limestone is traceable by its fragments, thickly strewn over the fields, and in the ditches surrounding them it is occasionally visible *in situ*. It is obscurely seen on the railway north-west of Metheringham, and consists of hard blue shelly ragstone with clay bands, also crowded with fossils, *Ostrea* predominating. The east side of Dunston village is situated on this rock, which is occasionally exposed in foundations, &c. A small outlier has been detected east of Dunston Station.

The limestone appears in the bed of the brook at Nocton, and forms a bold feature half a mile further northwards. It is again laid bare in the stream west of Potter Hanworth Church, and a small outlier was revealed in 1882 by the lowering of the road at the Station.

It is next seen in the ditch at the boundary of the City of Lincoln, and on the north side of the wood it forms a hard bottom for a considerable length of the ditch, extending to the road. It is exposed in ditch-sections on both sides of the little valley half a mile to the north-west of this, and its lower beds are seen in the Heighington railway cutting to a depth of 8 feet; they abound with the usual Brachiopoda and oysters, and lie in a slight synclinal with a general eastward dip.

The rock is again seen in the brook east of the village, and in a small exposure a quarter of a mile to the south; thence it rises to cap the hill to the north, but is obscured on the east by gravel.

It is next seen in the road on each side of the little hollow east of Greetwell, and exhibits a sharp dip to the east. Where the railway cutting crosses the promontory of this rock, the section is much obscured; but the faulted-down outcrop, 16 chains westward of the bridge, is the most complete exposure in the district, the full thickness of the rock being laid bare on a face the slope or "batter" of which permits of examination in the completest detail. There appears to be a gradual passage from the clay below, through marl, to the hard ragstone constituting the bulk of the rock, which abounds in fossils of various classes. Among these are palatal teeth of Fish, Mollusca, Echinoderms, and Corals. The rock is 15 feet thick, and dips to the north-east at 14° at the base, rapidly flattening eastward, and becoming nearly horizontal at the fault which brings it against the Inferior Oolite. The fault strikes W.N.W., and slickensides and spar are observable on the faces of rock brought into contact by it.

Eastward of Bunkers Hill, the limestone is well seen in the Reepham brook, and the fields at its source (Cunsike Spring) are thickly strewn with fragments. Two small ponds at Nettleham Lodge, three-quarters of a mile south-east of the village, are dug in the rock, which was also revealed by draining north of Nettleham. From near Friezeland to Welton the rock is intersected by deep ditches, artificial drainage being necessitated by its waterlogged condition. Such exposures are also abundant near Honeyholes and north of Hackthorn, both on the bridle-road to West Firsby, and in the fields right and left of it. In the streams constituting the head waters of the Ancholme, small exposures are seen westward of Spridlington and Saxby, and the rock is raised for road-metal in a series of old quarries, from a mile to a mile and a quarter, westward of the latter village.

W. H. D.

At the cross lanes, or path-roads, north of West Firsby, Great Oolite Limestones are exposed, dipping in an easterly direction at 2°; the exposure continues for some chains by the turning to Saxby, the limestones being visible to a depth of 5 feet, in horizontal beds.

In a small quarry on the north-west side of the cross lanes, 7 feet of Great Oolite Limestone is exposed; the beds undulate, dipping north at 5°, and N. 40° E. at 2°.

At a quarter of a mile north of the cross lanes, Great Oolite Limestone is exposed to a depth of 2 feet in a ditch. Further north, it is exposed to a depth of from 2 to 3 feet by the road to the Lodge, at the ninth milestone on Ermine Street. The limestone is also shown in a drain on the south of this road at half a mile east from the turning to West Firsby.

At about a mile west from Owmbly Church, Great Oolite Limestone is exposed to a depth of from 6 to 9 feet in a quarry. In one part of the quarry the lateral divisions, which, as a rule, give the rock a shaly appearance, are not developed, so that the section seems to consist of three or four distinct beds, in descending order, as follows:—

	Ft.	In.
Grey, partly crystalline, limestone (often of a pepper and salt grey hue), with numerous fossils - - -	2	0
Limestones similar to above - - -	2	0
Hard, comparatively unfossiliferous, blue limestone	1	6

In other parts of the quarry the rock splits into shaly pieces, of from 1 to 3 inches in thickness, but lines of more shaly material give to it on the whole a distinctly bedded aspect; the beds are horizontal. In the western parts of the quarry, from 5 to 6 feet from the surface, the beds are fossiliferous and partly crystalline, the limestone often presents a somewhat granular texture, and the mixed grey (pepper and salt) colour. From these beds, for 4 or 5 feet downwards, hard bluish-grey, less fossiliferous limestones extend, resting upon an irregular bed of blue limestone, which forms the floor of the quarry. Impersistent beds of brown sandy ferruginous rock occur in the limestones at between 3 and 6 feet from the surface.

At about 30 chains south of Normanby Cliff Farms a foot of Great Oolite Limestone is exposed.

Near the letter *C* in the words Normanby Cliff, and the *N* in the words Normanby Mill on the Map, rock is exposed, to a depth of 5 feet in the former place.

At a mile west of Normanby Church, on the north side of the road, a quarry shows from 6 to 8 feet of grey Great Oolite Limestone.

By the bridle-road to Caenby the rock is exposed in ditches on either side of Low Walk Wood houses, also by the eastern boundary of the wood, and in a continuous section in a drain east-south-east of the wood and nearly parallel with the road-track. In the drain, Boulder Clay conceals the rock in places. Great Oolite Limestone is further evidenced by surface stones north of Low Walk Wood, and it is exposed in a drain running in a southerly direction from the road to Caenby, at about a quarter of a mile west of Low Walk Wood houses.

East of Spital and south of Norton Place Park, Great Oolite Limestone is exposed by the path roads, and in drains and ditches between them. In one drain about a mile and a quarter due east from the little church at Spital, the upper bed resembles Cornbrash in external appearance.

The outliers of Great Oolite at the 12th milestone on Ermine Street are evidenced by feature and surface stones on the west, by feature (slight) and partial exposure in a ditch on the east.

At about half a mile east from Norton Place House, in a ditch by the north side of the plantation, the junction of the Great Oolite Limestone and Upper Estuarine beds is shown. The section is shown in the accompanying figure:—

FIG. 3.

E. Ditch section half a mile east of Norton Place House. W.



Horizontal scale, 1 inch = 40 yards.

Reddish brown and drab surface sand (s.) caps the section. Proceeding from west to east we encounter (c.) rubbly fossiliferous rock with *Avicula*, *Rhynchonella*, and Univalves, from 6 inches to 2 feet thick, upon (d.) a mass of broken *Ostreae* in a clayey matrix. At x red brown sand with small stones, more or less worn, may be a relic of fluvial deposit, or of Glacial Drift; abutting against it is stiff grey clay (e.), overlain by (f.) Great Oolite Limestone, 2 feet thick, in stone beds which seem to pass out eastward into rubbly bands of broken *Ostreae*; at 4 chains further east, the hard rock seems to predominate, but it is associated with the broken shelly matter.

We have here the type so frequently exhibited by the Great Oolite from Snitterby northward into Sheet 86, namely, the irregular association of tolerably hard irregular shaly limestones with softer beds of decomposed fossiliferous limestone, or of broken shells in a loamy or clayey matrix.

As (c.) is evidently the hard bottom bed of (f.) its position must be due either to a small fault at x, or to pressure. The surface fragments in this ditch section very strongly resemble Cornbrash.

On the east of Norton Place fossiliferous limestone fragments, greatly resembling Cornbrash, occur on the surface, and have also been brought up with the roots of fallen trees in the plantations near the house. Similar fragments are usually found in the higher parts, on the surface and in drains; at a slightly less elevation Great Oolite Limestone fragments are abundant, the surface soil being reddish brown and sandy, with bits of flint, and occasionally foreign fragments. From the above indications an outlier of Cornbrash was first carefully mapped, but the absence of Great Oolite Clay to separate it from the Great Oolite Limestone proved an insuperable obstacle to that idea, which was abandoned, as also ideas of glacial transport, the simple explanation being, the existence in the Great Oolite of beds lithologically and palaeontologically very similar to the Cornbrash; a like difficulty was experienced in Sheet 86, near Waddingham, which was only cleared up by the evidence obtained in mapping the Bishops Norton area.

On the north of Norton Place, south of the Lodge, the boundary of the Upper Estuarine beds and Great Oolite Limestone is by no means clear, a bed or two of siliceous limestone was noticed in a drain, apparently in the Upper Estuarine Series.

Great Oolite Limestone is at the surface in the village of Bishops Norton; it is also exposed in a quarry at about a quarter of a mile from the village on the east.

By the turning from the Atterby and Snitterby road, towards Sminhays, Great Oolite Limestones are exposed in a ditch for some distance.

Near Snitterby, on the south, Great Oolite Limestones are exposed in small pits, also by the road on the east side of the village, and in drains east of the Rectory.

Great Oolite Clay.

The Great Oolite Clay occupies the outcrop slope of the Cornbrash escarpment feature, but its breadth expands in places where it has been spared by denudation on the lower part of the dip-slope of the subjacent limestones, as appears to be the case west of Saxby, and where the Cornbrash has been denuded from the crest of its feature, as exemplified on the west of Reepham. The Great Oolite Clay is affected by faults between Dunston and Nocton, and near Lady Wood (between Heighington and Potter Hanworth), on the south of the Witham valley; it is concealed by Drift near Metherringham, Nocton, Potter Hanworth, in several places between Reepham and Welton, and near Normanby Mill.

The clay is about 25 feet* in thickness; it is of a dark bluish-grey colour often mottled with green, and contains numerous

* *Vide* Appendix, Sudbrooke Holme well.

shells, principally *Ostreæ*, which, as far as the limited depth of its exposures permit of judging, are most abundant at its junction with the Cornbrash.

In the Well at Sudbrook Holme the Great Oolite Clay is described as :—

		Ft.	In.	Ft.	In.
Green clay	-	11	6	} 25	6
Dark clay	-	14	0		

Mr. Dalton remarks :—This series is rarely more than 20 feet in thickness, consisting of blue clays, weathering yellow to a considerable depth, atmospheric action being aided by the abundance of shells rendering the clay fairly permeable. From the rarity of exposures, other than mere ditch-sections, the fossils have not been much studied, but appear to be numerous in individuals rather than in species, *Ostreæ* and *Rhynchonellæ* preponderating.

An old brickyard near Metheringham Station was worked in these clays, which were also raised in draining between here and Dunston.

They were seen near Nocton Hall in ditches and in the brook, and in the fields north-west of Potter Hanworth. Near Lady Wood and to the north they are largely concealed by gravel, which, towards Heighington, covers more than half of their narrow outcrop. The hill north-east of Heighington is likewise poor in exposures, the wash of gravel down the slopes affording natural drainage on what, nevertheless, we must map as clay land, disregarding material not in place.

West of Cherry Willingham is an obscured railway cutting in these clays; they were also deeply drained in 1883, midway between Cherry Willingham and Nettleham. They were also seen north and south of Sudbrook, in the flanks of the feeders of the Langworth that pass by that village. Eastward of Welton several small exposures were seen, and the clays are revealed in ditch sections near Hackthorn Mill and Spridlington. Westward of Saxby, by a freak of denudation, the outcrop is widened to nearly three-quarters of a mile. The patch of Boulder Clay has probably assisted in protecting the clay whilst the Cornbrash has, owing to the approach of two streams, receded, leaving an outlier only, in the average position of its escarpment.

W. H. D.

From Saxby northward its position between two hard beds would render the Great Oolite Clay an easy division to trace, in spite of the general absence of good exposures, were it not that three patches of Boulder Clay, west of Saxby and Owmbly, render its junction with the underlying limestone uncertain, more especially in the vicinity of Normanby Mill.

Near the road to the Ermine Street, at about half-a-mile from Saxby Church, dark grey and green Great Oolite Clay was shown in a ditch.

In a ditch running nearly east and west across the Cornbrash feature, between Normanby and Caenby, the evidence proceeding east from the stream between Normanby Mill and Glentham Mill is as follows :—

For 6 chains from the stream, soil, apparently alluvial, on Great Oolite Limestone. For 6 chains up the slope, bluish and greenish Great Oolite Clay, probably under a Boulder Clay soil. For 30 yards, a brown soil with small fragments of Cornbrash upon greenish and dark grey clay, apparently mashed or squeezed up with broken pieces of Cornbrash; the ditch here is from 3 to 4 feet deep. For 6 chains, Cornbrash, on Great Oolite Clay full of *Ostreæ*. For 94 yards, Cornbrash resting irregularly upon Great Oolite Clay. At this point, about 24 chains east from the stream, the Great Oolite Clay is near the surface. At about a hundred yards further on, greenish clay is

visible. At 6 chains further east, Great Oolite Clay is shown at the bottom of the ditch, and at about 4 chains further, and 9 chains from the road to Caenby, it is exposed under from 1 to 2 feet of Cornbrash.

By the high road near Glenthams Mill, dark grey Great Oolite Clay is exposed.

Great Oolite Clay was turned out from drains on the slope below the Cornbrash both north and south of the road from Bishops Norton to Glenthams.

Great Oolite Clay is exposed near its junction with the Cornbrash east of Bishops Norton.

From Sminhays northward the Great Oolite Clay is entirely concealed by sand and gravel, the next evidence of it at the surface being near Old Mill and Waddingham in Sheet 86.

Cornbrash.

The Cornbrash in Sheet 83 is very thin, being from 3 to 5 feet; but its characteristic appearance, as described by Professor Judd,* makes it at once the most distinctive and persistent member of the Great Oolite Series, although there are fossiliferous beds locally present in the Great Oolite Limestone which are hardly distinguishable from it.

From the crest of its escarpment the Cornbrash falls gently eastward to the foot of the Kellaways Rock feature; the breadth of its outcrop is considerably less than that of the Great Oolite Limestone.

The continuity of the Cornbrash is broken by faults in two places south of the Witham valley, near Dunston and Lady Wood; but near the latter place and around Potter Hanworth it is concealed by Glacial deposits, and by gravels near Metheringham and Blankney.

West and south of Reepham, north of the Witham valley, the Cornbrash is concealed by Boulder Clay, by which it is also partially covered in several places as far north as Welton.

The Sudbrook Holme boring describes the Cornbrash as stone, 4 feet 6 inches in thickness, separated by 7 feet of blue clay from the Kellaways Sand above, and resting upon Great Oolite Clay 25½ feet thick.

The following notes on the southern part of the Sheet are by Messrs. Penning and Dalton:—

Mr. Penning remarks:—The most southerly exposure of the Cornbrash in Sheet 83 is a small pit, 2 or 3 feet deep only, about three-quarters of a mile eastward of Scopwick. The rock here is, as usual, a thin-bedded shelly limestone of ferruginous aspect, but the flakes when broken show a deep-blue interior. The very limited extent of the weathering may be due to the comparatively recent removal of the protecting Oxford Clay, but the compact crystalline character of the rock probably accounts for the arrest of the oxidation.

W. H. P.

A trace of the rock, much disintegrated, was observed in the making of the road from Metheringham Station to Blankney Hall. A fairly persistent feature extends thence to Dunston, where the rock is seen in the brook and in a little quarry north of the fault. Thence it forms a well-marked escarpment and dip-slope to Potter Hanworth, whence it is lost under Boulder Clay and gravel for about a mile.

* *Geology of Rutland*, Geol. Survey Memoir, pp. 218, 219.

The outlier south of Lady Wood is indicated by feature, and the rock was exposed in a fresh-cut ditch in 1883; its presence on the hill south-east of Heighington was determined by similar evidence.

W. H. D.

In the fields south of Cherry Willingham the rubbly top of the Cornbrash is raised for road-metal, and an abandoned pit half a mile west of the village showed, in 1878, similar rubbly siliceous bluish ragstone. Half a mile to the north of the village there were, at that time, two small pits now filled up, in which were noted the following particulars:—

Grey Boulder Clay, in patches, attaining a thickness of 3 feet.

Loamy sand (probably Kellaways Sand) in places as much as 4 feet thick.

Blue silty clay of varying thickness, probably averaging 1 foot.

Hard blue shelly limestone, weathering brown, with much fossil wood and plant-markings.

W. H. P.

The rock is seen in the brook below and in the meadows to the east, and was laid bare in draining on the hill between the brook and the Roman Road to the north, on which appear to be two small outliers of Cornbrash.

The large, though shallow, pits in the south-west part of Sudbrook Holme Park have yielded to the assiduous researches of Mr. Carr, of Lincoln, no fewer than 80 species of fossils.

The rock is seen at intervals, north of Sudbrook, round the hill into Soothern; it is quarried three-quarters of a mile north-north-west of that village, and at Dunholme, where the clay at the base of the Kellaways Beds is seen overlying it.

There are two small quarries by the road from Welton to Cold Hanworth, and many small exposures in roadside ditches and in the fields on either side of the way to Spirdlington. A well-marked feature is persistent throughout, but at Saxby its place is represented by an outlier only, the streams having cut down to the subjacent clays on either side backwards to their junction.

W. H. D.

In the valley near Saxby, on the west, the Cornbrash is for the most part concealed by river valley-gravel, but a small outlying patch of it (mentioned above) caps a low mound bounding the gravel tract on the west, and showing Great Oolite Clay ploughed up on its slopes.

From Saxby northward, the Cornbrash is well evidenced by feature, and frequently also by surface soil, the rock being so homogeneous in character that a description of its appearance in one exposure would, except as regards thickness, apply to all. There is no evidence that the Cornbrash attains a greater thickness than 4 feet.

Near Normanby Mill the Cornbrash has been ploughed up on its feature.

By the road from Normanby to Caenby, Cornbrash with its characteristic fossils has been turned out of the ditch. A drain running across the Cornbrash feature nearly west from the road, (the evidence in detail is given in the notes on Great Oolite Clay) shows from 1 to 2 feet of Cornbrash at 9 chains from the road, and for nearly 20 chains further west the Cornbrash is visible at intervals upon the Great Oolite Clay, its irregular junction with it being due, either to minute undulations or to surface pressure, as there is a strong probability that glacial agency in some form operated upon the dip-slope of the Cornbrash.

Cornbrash is also exposed in a drain running south-south-west from this ditch, at about 18 chains from the road.

West of Caenby, the evidence on the Cornbrash dip-slope is very obscure; the sides of a pond by the road show no signs of the rock; so we are forced to conclude, either that the Cornbrash is concealed by a Boulder Clay soil, or that it has been partially denuded from its dip-slope, and that an inlying patch of the underlying Great Oolite Clay forms the surface.

A similar difficulty is experienced on the north of Glentham, where the Cornbrash appears to be concealed by Boulder Clay soil extending southward from what appears to be a genuine patch of Boulder Clay.

Cornbrash is exposed by a farmyard in the northern part of Glentham, on the west side of the road to Bishops Norton.

Cornbrash has been turned out of drains traversing its feature on the south-east of Bishops Norton; it is also exposed in drains on the north and south of the road from Bishops Norton to the Ancholme.

At about a mile east of Bishops Norton the dip-slope of the Cornbrash is strewn with its characteristic fragments and fossils, *Holcotypus depressus* being abundant; but as we approach the stream, foreign fragments on the surface suggest the concealment of the rock by a thin strip of Boulder Clay: if this is the case, it is quite possible that the Cornbrash may have been denuded down to the underlying clay as far south as the road to Bishops Norton.

About Sminhays the outcrop of the Cornbrash is very narrow, and hardly makes a feature; but toward the road to Snitterby it widens. On the north of the road to Snitterby the Cornbrash is scarcely indicated, being covered by superficial sand as it passes northward into Sheet 86.

The following are a few of the fossils obtained from the Cornbrash of the Normanby district:—

Acrosalenia.
Anabacia orbulites, D'Orb.
Holcotypus depressus, Leske.
 * *Rhynchonella concinna*, Sow.
Waldheimia obovata, Sow.
Terebratula intermedia, Sow.
Trigonia, like *Tundulata*.
Opis.
Quenstedtia lævigata, Phill.

No systematic search for fossils was undertaken; but as the rock is invariably fossiliferous, the *Echini* and *Terebratulae*, weathered out of it, being scattered over the ploughed portions of the dip-slope of the Cornbrash, the above list could be very easily extended.

W. A. E. U.

CHAPTER IX.*

MIDDLE AND UPPER OOLITES.

In Lincolnshire these groups are represented only by the Kellaways Beds, and the Oxford and Kimeridge Clays. The Corallian group is entirely absent, and the Oxford Clay passes up into the Lower Kimeridge without the development of any bed which can be taken as forming a line of division. The Portland series is also absent, so that, intervening between the sandy Kellaways beds and the Lower Neocomian Sands, we have a great continuous series of clays and shales some 800 or 900 feet thick. The breadth of ground occupied by this great clay series is from 13 to 14 miles in the south part of Sheet 83, but narrows northward till along the north edge of the sheet it only measures seven miles. This seems to be caused partly by the thinning of the series northward, and partly by the overstep of the Cretaceous series.

The Kellaways Beds consist of sands and sandstones, separated from the subjacent Cornbrash by a few feet of black shales, and passing upwards into the Oxford Clay. Their outcrop was mapped by Messrs. Ussher and Dalton.

A. J. J.-B.

Mr. Ussher contributes the following notes:—

Basement Clays.

The Kellaways Rock does not appear to rest directly upon Cornbrash rock, as, if so, the escarpment slope of the former would give to it a greater thickness and consequent importance than we are inclined to assign to it. In Yorkshire, these beds are separated by about 15 feet of shales, "the *Avicula* Shales" of Mr. Hudleston, "the Cornbrash Clay" of the Survey. In the Midland Counties, clays are associated with the sands of the Kellaways Rock, and do, in some cases, separate it from the Cornbrash (Geology of Rutland, p. 236, quoted from Prof. Morris' description of the Casewick Railway cutting). "Resting upon this bed (the Cornbrash) is the equivalent of the Oxford Clay, consisting of 10 feet of dark laminated unctuous clay, with gray-brown sandy ferruginous clay. The dark clay contained *Ammonites Herveyi* abundantly, as well as *Modiola bipartita*, *Trigonia clavellata*, *Thracia depressa*, *Nucula nuda*, Phil. and Saurian bones," (vide also Ibid, p. 237). Prof. Judd includes these clays in the Kellaways series or lower part of the Oxfordian. The Cornbrash Clay is thus described (Geological Survey Memoirs, Descriptions of Sheets 95 S.W., and 95 S.E., 1880, pp. 10, 11), "Above this are about 6 feet of finely laminated bluish-grey shale, containing *Avicula echinata*, *Glyphæa† Stricklandi* the so-called 'Clays of the

* Written, except where otherwise noted, by Mr. A. J. Jukes-Browne.

† In the Survey Memoir this is erroneously printed *Gryphæa*.

Cornbrash,' which pass gradually up into the yellow argillaceous base of the Kellaways Rock." It does not appear that the Cornbrash Clays are less connected stratigraphically with the Kellaways Rock than the clays which have been included in the Oxfordian in the Midland Counties, and we may at any rate regard the beds as homotaxial, if not strictly contemporaneous. We should naturally expect to find some representative of this argillaceous base to the Kellaways in Lincolnshire, but exposures of clay upon this horizon are remarkably few and far between, in consequence, no doubt, of the friable character of the overlying sand carried down the escarpment face of the Kellaways by rain, &c. Independently of the evidence furnished by the Brigg boring in Sheet 86, and that at Sudbrook Holme in Sheet 83, the height of the Kellaways escarpment being greater than the estimated thickness of the sands would allow, and clay being exceptionally visible at or near its base, we should feel justified in regarding the occurrence of a clay stratum on this horizon as certain, although its persistence may be rather doubtful. To the south of Saxby the indications of clay occurring at the base of the Kellaways have been mapped as Oxfordian, and not separated on the principle adopted in the sheets to the south. To the north of Saxby, lines have been drawn on the map for the clays, in accordance with the mapping of this horizon in Sheet 86, which was completed before the mapping of the Lower Oolites in the north part of Sheet 83 was begun.

In the Brigg boring (*vide* Memoir on Sheet 86), 18 feet of shale was encountered between 2 feet of sandstone (the Kellaways) above, and 3 feet of limestone rock (the Cornbrash) below. In the vicinity of Brigg, the Kellaways is very thin, and to put any other construction on the succession than that given above would render the details incomprehensible.

In the Sudbrook Holme boring, which is about 19 miles to the south of that at Brigg, the succession is as follows:—

					Ft.	In.
Soil	-				2	0
Stone	-	-	-	-	5	0
Grey sand		-	-		13	0
Blue clay	-				7	0
Stone (Cornbrash)					4	6

Here we have 18 feet of Kellaways, as against 2 feet of that rock at Brigg, whilst the Clay below is 7 feet, as against 18 feet at Brigg.

Half a mile north of Cherry Willingham "blue silty clay of varying thickness" is noted by Mr. Penning as occurring in pits now filled up, upon the Cornbrash; his estimate of its thickness is rendered unsatisfactory by the doubtful age of the overlying sandy bed.

Mr. Dalton mentions the exposure of the basement clay at Scothern brook, at Dunholme, and near Rutton (see next page).

On the slope, just above the Cornbrash outcrop on the west of Saxby, dark grey clay was observed above the road, but no continuous exposure.

Near Caenby Old Hall the ground is very marshy, and there is a pond at the Hall, both indicative of a clay substratum masked by a wash of sand.

In the north part of Glenthams, clay is evidenced by several ponds just above the outcrop of the Cornbrash.

In the road east from Bishops Norton to the Ancholme, just above the Cornbrash feature, grey loamy clay was reached, by spudding through whitish sand.

At a quarter of a mile within Sheet 86, clay was indicated at 2 or 3 feet above the Cornbrash.

In all the above cases the evidence, without regard to the borings, points to the existence of a clayey stratum at the base of the Kellaways Rock, but the absence of exposures and of any indication of its palæontological affinities, gives no clue as to whether it should be included in the Middle Oolites above or bracketed with the Cornbrash below.

W. A. E. U.

Kellaways Rock.

The following notes are by Messrs. Dalton and Ussher :—

The sands are seen to form a slight escarpment from Kirkby Green, a mile eastward of Scopwick, to Blankney Grove. North of Metherringham they are full of soft tufaceous carbonate of lime, probably derived from the Boulder Clay. Eastward of Nocton Hall there are several shallow sand pits, capped in places with soft sandstone, which is crowded with ill-preserved specimens of *Gryphaea bilobata* and *Belemnites*. Similar beds are seen in a little pit half a mile northward of these, and there is a ploughed-down pit in the same south of the Potter Hanworth brook. Beyond this, the beds are concealed by Drift for two miles, and then the sands appear on the road three-quarters of a mile west of "The Green Tree."

Half-a-mile eastward of Cherry Willingham, a deep ditch gives a fine section of bright yellow and tawny sands, and these are also seen in the railway cutting at the west end of the village, and on the slopes of the valley above and below Reepham. Mr. Cameron has noted the Kellaways Rock on the top exposed in the road north of the station. The escarpment continues to Sudbrook Holme, north of which the sands and sandstone were well seen in draining near Scothern Mill, in 1882. The black clay-shale at the base of the series is seen in the brook at Scothern, and in the two Cornbrash pits at Dunholme, above which village the road to Snarford shows several feet of fairly massive rock.

Near Rutton all the members of the series are seen in isolated sections; the basement clay in a gravel pit, a quarter of a mile south of Rutton; the sands opposite the mill; and the rock in the stream east of the mill. The clay is again seen under gravel 200 yards north-west of Rutton, and at intervals in the bed of the main stream, the left bank of which is the well-marked escarpment of the sands, which continues to Saxby without other exposure than that furnished by shallow ditches. The basement clay extends up the dip-slope of the Cornbrash for a quarter of a mile along the road north-east of Hackthorn Grange.

W. H. D.

Near Saxby the Kellaways Beds are generally sufficiently well indicated by surface soil and feature to be traced with tolerable facility. They consist of sands which have, through the cementing matter of patches or lines of *Belemnites* and *Gryphaea*, been concreted into hard rock in places, very irregularly. From the preponderance of sand, which has no doubt been plentifully washed down its escarpment slope, we cannot be certain of its base within a few feet. The junction of the Kellaways with the Oxford clay is slightly marked by feature north of Saxby, and at Owmbly, and Normanby, but at Glenthams it is obscured by Chalky Boulder Clay, and between Glenthams and Sminhays two smaller patches of Boulder Clay conceal the junction.

Kellaways Rock is exposed by the road from Saxby to Spridlington, at about 12 chains from the former, and Kellaways Sand is shown a little further south.

At the bend in the road, just north of the turnings to Spridlington and Saxby, near the former, Kellaways Rock is visible in a ditch.

About Owmbly, Normanby, and Caenby, the Kellaways seems to consist almost entirely of sand, but I am told that about 18 inches of shelly rock has sometimes been encountered on sand in draining the land in the vicinity of Caenby Old Hall. Kellaways Sand covers the surface on the north of

Glenthams; it is exposed in several places. At a mile and a quarter from Glenthams Church, in a direction N. 15 E., Kellaways Rock is exposed in a ditch.

On the south side of the road to the Ancholme, at a mile east from Bishops Norton, the Kellaways Sand is exposed to a depth of $5\frac{1}{2}$ feet in a sand-pit.

The section is as follows :—

Surface soil, brownish sand with occasional bits of flint.

Kellaways Sand, buff and ochre-coloured sand, mottled with pale greenish hues, ferruginous in places, and exhibiting a tendency towards lamination. In the upper part of the sand, just under the surface soil, there are two masses of Kellaways Rock, one of them being very small. Water is held up by the bottom of the pit.

Kellaways Rock is better developed from this pit northward.

The rock is exposed at the turning towards Harlam Mill, in the roadside ditch, also in a drain cutting across the Kellaways dip-slope west; from the turning, Kellaways Sand is visible by the road near Sminhays, on the south and south-east. Near the road opposite the turning to Snitterby, Kellaways Rock, with the usual fossils, *Gryphæa bilobata* and *Belemnites* (which, it should be mentioned, occur in all its exposures), is exposed to a depth of two or three feet in a pit. The rock is also exposed on either side of the road to the Ancholme south-east of the pit, and by the Ancholme Alluvium at the northern margin of Sheet 83.

The common *Gryphæa bilobata* and *Belemnites* are never found in quantities, and, even individual specimens are rare in the Kellaways Sand. They abound in the Kellaways Rock, which is, as we have seen, far more prevalent within a mile and a half from the north margin of Sheet 83 than further south. This character is maintained in Sheet 86 on the north, where the irregularly associated sands were regarded as Drift, until the survey of the area to the south showed the true nature of the Kellaways.

W. A. E. U.

Oxford Clay.

The area occupied by this clay was surveyed by Messrs. Ussher, Dalton, Cameron, and Jukes-Browne; and the following description has been compiled from the notes obtained by each. The Oxford Clay is a thick-bedded dark-blue shale, losing its lamination, jointing, and colour, when exposed to atmospheric influences, and becoming a soft plastic pale-yellow clay. From the quantity of iron pyrites which it contains, either in nodules or disseminated through the mass, the weathering of the slopes of railway cuttings or abandoned pits proceeds but slowly, the acidity produced by oxidation of the pyrites checking vegetation, and its concomitant action on the subsoil by the penetration of roots, so that a slope of bare shale, comminuted on the surface by the mechanical influences of frost and drought, is only converted into clay by the ultimate lixiviation of all acid and the development of vegetation over its surface. The chemical action is promoted by the presence in percolating and surface water of bicarbonate of lime, derived from the generally present Boulder Clay. This, changing by mutual decomposition with the ferric sulphate to gypsum, diminishes mechanically the impermeability of the first-formed clay, whilst the oxidation of the

ferric carbonate to peroxide, and the reversal and repetition of that process by the alternate excess and disappearance of organic matter has probably a similar effect, admitting the access of the atmospheric agents to an interior layer of the mass.

W. H. D.

The following notes describe such exposures of the Oxford Clay as have been observed in Sheet 83, commencing at the southern border, near Timberland.

A large brickyard, half-a-mile north-east of Timberland Church, exposes about 6 feet of Oxford Clay beneath the Fen and Drift Deposits; the section here seen by Mr. Jukes-Browne in 1878 being given on p. 171.

The Oxford Clay is of a dark slate colour, and contains many fossils *Gryphæa dilatata* and the small *Ammonites* being scattered about the floor of the pit in abundance. The following were collected :—

Gryphæa dilatata, Sow.
Belemnites, sp.
Ammonites Lamberti, Sow.
A. Mariæ, D'Orb.
A. oculatus, Phil.

Still lower beds are seen in the trenches along the railway east of Scopwick and Blankney, and in a brickyard on Cottagers Common, but the excavations are only shallow.

North of this the Oxford Clay is greatly obscured by drifts, and nothing but ditch-sections were found on the west side of the Witham Fens.

On the east side of these Fens the Upper Oxford Clay sets in near Bardney, and is exposed for some 40 feet in the large brickyard near the Station. It is a stiff blue clay, containing the following fossils, identified by Mr. Sharman :—

<i>Ichthyosaurus</i> (vertebra).	<i>Ammonites cordatus</i> , Sow.
<i>Ammonites perarmatus</i> , Sow.	„ <i>excavatus</i> , Sow.
<i>A. biplex</i> , Sow.	„ <i>plicatilis</i> , Sow.
<i>A. macrocephalus</i> , Schloth.	<i>Gryphæa dilatata</i> , Sow.
<i>A. arduenensis</i> , D'Orb.	<i>Serpula sulcata</i> , Sow.

The same beds, with *Amn. perarmatus*, were found in the valley near Rand, about five miles to the northward.

A. J. J.-B.

Mr. Dalton continues the description as follows :—

Lower beds are seen in an old brickyard near the east end of Fiskerton Long Wood, and from thence in ditch-sections to Fiskerton. There are casual exposures in the hollows north and south of Langworth station, and here and there near the outcrop of the Kellaways Beds to Spridlington.

The clays dug in the Langworth Bridge brickyard contain *Ammonites Lamberti* and *Gryphæa dilatata*; similar clays were seen in various ditch-sections about Scotern Grange, and constitute the base of the slopes of the Langworth valley northwards of Swinhorpe. They are worked for bricks at Snarford Hill, and were worked formerly a quarter of a mile east of Fristhorpe. Besides frequent but unimportant ditch-sections, the only notable exposures are in a gravel pit a mile west of Wickenby station, and the deep drains in the flat clay lands east of Cold Hanworth, which show the weathered clay on their banks and (at the periodical clearings) the unaltered blue clay in their wide floors.

Half a mile west of East Firsby there is an old brickyard with Oxford Clay, which is also seen in the brooks and ditches hereabouts.

In all these places, *Gryphæa dilatata* was observed, but no other fossils were obtained.

W. H. D.

Mr. Ussher, in describing the northern part of the Sheet, remarks :—

North of Spridlington the Oxford Clay on the west of the Ancholme Valley is to a great extent concealed by Chalky Boulder Clay; the largest tract formed of it superficially is near Bishops Bridge.

At half a mile east of Normanby (by Spital) Church, a brick-pit about 180 yards long from north to south, exposes Oxford Clay to a depth of from 3 to

5 feet; the clay is stiff and bluish-grey mottled, or marbled, with buff or brown; it is capped by pockets of reddish-brown sandy matter and grey clay with small angular flints under about a foot of drab soil.

At the bend in the high road to Glenthams, near Bishops Bridge, a well was sunk in 1883 in the Oxford Clay. For about 6 feet down it was mottled, or marbled, with yellowish brown or buff tints; below that, it consisted of dark grey rather shaly clay from which the following fossils, in a pyritized condition, were obtained.

Nucula? sp.

A. Duncani, Sow.

Ammonites plicatilis, Sow.

A. Lamberti, Sow.

A. hecticus, Rein, var. *canaliculatus*.

Grey and brownish Oxford Clay is exposed in the drains on the flattish tract extending in a north-easterly direction from the well. A mile from Glenthams Church in a direction N. 30 E., Chalky Boulder Clay is shown in a pit, resting on Oxford Clay; the latter consists of bluish-grey clay mottled yellowish-brown, and exhibiting a shaly splitting tendency, and cutting like cheese. The same texture is exhibited by the clay exposed at 8 chains south of the pit, where stiff bluish and chocolate-brown clay was proved to a depth of $2\frac{1}{2}$ feet under superficial sand.

At about a quarter of a mile north-west from the pit above mentioned, about a foot of grey clay was observed in a ditch, resting on yellowish sand; it is overlain by sandy soil with flints. As it occurs where the junction of the Oxford Clay with the underlying Kellaways Rock should be, it has been taken as evidence of the position of this boundary.

By the road toward Harlam Mill, at a mile and three-quarters east of Atterby, laminated bluish-grey Oxford Clay is exposed in a brick-pit under a Drift soil.

The junction between the Oxford Clay and Kellaways Rock, when not concealed by Boulder Clay, as north of Glenthams and east of Bishops Norton, is usually marked by feature, breaking or diversifying the slight dip-slope of the Kellaways Rock.

W. A. E. U.

Kimeridge Clay.

As already stated (p. 73), there is a complete passage from the Oxford into the Kimeridge Clay, making it difficult to draw any line of division between them. The boundary shown on the map has been drawn along a strip of country between the places where either clay can be identified with any certainty.

Near Bardney the position of this zone of passage can be fixed with tolerable certainty for there are two brickyards within little more than a mile of each other, one of which, as already mentioned, contains Oxford Clay fossils; while the other yields species characteristic of Kimeridge Clay. Hence the passage beds must run along the strip of country between them.

North of this, the line of junction is entirely hypothetical, as no open sections have been observed anywhere near it, except at Rand, where *Ammonites perarmatus* indicates Oxford Clay.

Dark clays with large septaria containing serpulæ were observed in small field-pits between West and Middle Rasen and at Osgodby, but no depth was exposed. The brickyard south of Osgodby Mill must have given a section of these passage beds, but is now abandoned and overgrown. Prof. Blake, however, examined the spoil from a well-sinking on the main road near here, and found "black clays with white rotten fossils in layers, most of them being undistinguishable, but *Gryphæa dilatata* and *Belemnites* were plentiful;" he also obtained a reptilian bone bearing a

specimen of *Discina humphresiana*, and he remarks that the Belemnites were not hastate, but comparable with *B. nitidus*. He regards these clays as identical with those seen in the railway cutting west of Wrawby in Sheet 86.

From the collections made by Prof. J. F. Blake and by the Survey fossil collector, it would appear that the Kimeridge Clay may be divided into a lower and upper portion, the former including the great mass of the formation.

The Lower Kimeridge Clay contains many species which are usually considered as Oxford Clay forms, such as *Ammonites plicatilis* and *Gryphæa dilatata*; but this mixture of species appears to be greater in the north of Lincolnshire than in the south part of Sheet 83; but throughout the county, *Lingula ovalis*, *Thracia depressa*, and *Ostrea deltoidea* may be taken as evidence of the beds containing being Kimeridge Clay.

The upper portion of the clay consists of grey and black shales, with layers of limestone doggers, sometimes forming continuous floors of poor hydraulic limestone. Some of the shales are bituminous; others are grey, dry, and papery.

Lower Kimeridge.

The lowest beds are exposed in a brickyard about a mile south-east of Bardney Church. They consist of black shales, about 13 feet of which are seen below the superficial deposits, and they have yielded the following fossils:—

<i>Belemnites Owenii</i> , Pratt.	<i>Thracia depressa</i> , Sow.
<i>B. abbreviatus</i> , Miller.	<i>Cucullæa longipunctata</i> , Blake.
<i>Ammonites</i> , sp.	<i>Astarte supracorallina</i> , D'Orb.
<i>Spinigera</i> , sp.	<i>Avicula</i> , sp.
<i>Dentalium</i> († <i>Quenstedti</i>).	Head of Fish.*

In a drain near Campney, *Ammonites plicatilis*, *Am. mutabilis*, and *Am. rotundus* were found.

Further south-east, between Stixwoud and Woodhall Spa, and about 6 furlongs from the latter, is a brickyard, now closed, but open in 1871 when the following section was taken by Mr. Skertchly:—

					Ft.
Superficial Deposits.	{	Sand, false-bedded, with a few pebbles	-	-	11
		Fine gravel	-	-	1
Kimeridge Clay.	{	Soft dark-blue clay	-	-	6
		Line of septaria full of serpulæ	-	-	1
		Soft dark-blue clay	-	-	6
		Course of septaria.			

Mr. J. F. Blake records the following fossils from this pit:—

<i>Belemnites nitidus</i> , Dollf.	<i>Ostrea deltoidea</i> , Sow.
<i>Ammonites serratus</i> , Sow.	<i>Lima ædignensis</i> , Blake.
<i>Rissoa mosensis</i> , Buv.	<i>Thracia depressa</i> , Sow.
<i>Avicula ædignensis</i> , Blake.	<i>Arca</i> , sp.
<i>Cyprina cyreniformis</i> , Blake.	<i>Serpula tetragona</i> , Sow.

Some of the above-mentioned species were also found by Mr. Blake in a small pit near Hawstead Hall, north-east of Stixwoud.

No exposures are to be found for some distance to the eastward, the next being a brickyard near Langton, west-south-west of Horncastle; the clay here contains large ferruginous concretions, and the fossils found by Mr. Blake

* Obtained from the workmen by Mr. Cameron.

are given in the Table (Appendix, p. 191). It is noticeable that *Ammonites serratus* still occurs at this horizon, but is not found at the Horncastle pits mentioned below.

At Horncastle there are three brickyards, one south of Thimbleby House, on the west side of the Bain, and two deep pits on the east side of the valley nearer the town. The *Ammonites* are *A. biplex* and *A. mutabilis*, and the rest of the fossils obtained here by Mr. Blake are given on p. 191.

In traversing the ground between Bardney and Horncastle, the observer will have passed over the greater part of the Lower Kimeridge Clay. The sections to the north of this line will now be noticed.

The first is a brickyard on the Wragby road, one mile and a half W.N.W. of Baumber. Mr. Strahan describes this as dug in laminated shale, with numerous flattened septaria, ranging up to $4\frac{1}{2}$ feet in diameter by about 1 foot in thickness; there are also hardened masses of clay traversed by threads or films of a whitish mineral (? selenite), enclosing a calcareous nucleus. The commonest *Ammonites* are: *A. Berryeri* and *A. serratus*, and the shales must be on about the same horizon as those at Langton. For other fossils see Appendix, p. 191.

Mr. Strahan remarks that the valley of the Bain, from Baumber to Benniworth has gently-sloping sides of Kimeridge Clay, in which pits have been opened in former times for obtaining clay to spread on the land. These pits are now overgrown, and full of water.

Nearer Wragby, and five furlongs W.S.W. of Hatton, is another brickyard, which was visited by Mr. Cameron, who found about 4 feet of black shaly clay exposed beneath the superficial deposits; the clay contains calcareous concretions, and the following fossils were obtained:—

<i>Ichthyosaurus</i> , sp. (vertebræ).	<i>Belemnites abbreviatus</i> , Mill.
<i>Pliosaurus</i> , sp. (paddle).	<i>Pleurotomaria reticulata</i> , Sow.
<i>Ammonites rotundus</i> , Sow.	<i>Inoceramus</i> , sp.
<i>A. alternans</i> , Buch.	<i>Ostrea</i> , sp.

The next exposures are those near Market Rasen. In the railway cutting, south of the town, Mr. Strahan found laminated clay, with *Ammonites mutabilis*, *A. rotundus*, and *A. alternans*.

At the brickyard three-quarters of a mile east-south-east of the church, the section is as follows:—

Clean yellow sand, current-bedded (moor sand)	Fr.
Dark bluish-black clay, shaly when dry	7
Course of hard calcareous rock	16
Dark clay below (according to workmen).	0½

This pit has long been celebrated for the beauty and variety of the fossils found in it; most of them occur just above the band of rock, but calcareous concretions occur throughout, and many of these contain *Ammonites*. For full list see p. 191.

Another pit, half a mile north-east of the church, shows a similar section. Here Mr. Strahan obtained the following fossils:—

<i>Ammonites alternans</i> , Buch.	<i>Lucina</i> , sp.
„ <i>rotundus</i> , Sow.	<i>Thracia depressa</i> , Sow.
„ <i>triplicatus</i> , Sow., var. ?	<i>Inoceramus</i> , sp.

On the flanks of Hamilton Hill there are old pits, showing blue clay with septaria and fragments of fossils, but the sections are obscured by slipping. Mr. Blake, however, records the following fossils from this locality, and considers it to be a higher horizon than the pits above mentioned:—

<i>Ammonites Berryeri</i> , Les.	<i>Avicula nummulina</i> , Blake.
„ <i>biplex</i> , Sow.	<i>Astarte supracorallina</i> , D'Orb.
„ <i>yo</i> ? D'Orb.	<i>Rhynchonella pinguis</i> , Röm.
<i>Nucula obliquata</i> , Blake.	

There is another brickyard (not now worked) by the Caistor road, a mile and a quarter north of Market Rasen; here many of the same Market Rasen fossils were found by Mr. Blake.*

* See *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 209.

Upper Kimeridge.

This division enters the sheet to the north-east of West Ashby, and the blue clay seen beneath Boulder Clay in the pit marked "kiln" on the map, one mile north-east of Ashby, probably belongs to it.

It is much better exposed in a brickyard at Goulsby (one-third of a mile south-south-east of the church), where Mr. Blake saw the following section:—

	Ft.	In.
Papery shales - - - - -	0	9
Blue dicey clay - - - - -	3	4
Harder fossiliferous band - - - - -	1	6
Blue clay, with nodules at the base - - - - -	14	0
	19	7

The fossils obtained here were: *Ammonites biplex*, *Lucina minuscula*, *Ostrea gibbosa*, *Discina latissima*, and *Belemniteuthis antiquus*(?); the surfaces of some of the shales being crowded with the small bivalves.

The railway cuttings near South Willingham are now completely obscured. Mr. Blake gives the following section as seen in one of them:—

	Ft.	In.
Thin limestone band - - - - -	0	4
Blue shale - - - - -	9	0
Band of hydraulic limestone - - - - -	0	8
Light blue dicey clay - - - - -	-	-

From the limestone he obtained *Ammonites pectinatus*, *Lucina minuscula*, *Ostrea gibbosa*, and *Discina latissima*.

A. J. J.-B.

Of the kiln near South Willingham Station, Mr. Strahan supplies the following account:—The blue clay used for bricks extends to a depth of about 8 feet in the present working (1882). At its base it is full of very large septaria, averaging from 3 to 4 feet in diameter, by about 1½ feet thickness. These septaria break up readily in the weather; the outer portions consist of a blue argillaceous limestone of an earthy texture, traversed by cracks filled, or partly filled, with dogtooth calcite; in the centre is a heart almost entirely made up of calcite. This limestone was sent to Hull to be tried for hydraulic cement, but proved worthless. Below the layer of septaria there occur bands of a hard inflammable oil shale, locally known as "dice." The bands are 4 to 6 inches thick, and are separated by blue clay. Fragments of dice readily blaze when dry, and leave a copious grey ash, giving off a most offensive smell while burning. It is said that the clay from this pit, when made up into bricks and ignited in the kiln, to a certain extent supports combustion, giving off a poisonous vapour that is highly prejudicial to vegetation. About Willingham water is got in some of the shallow wells from the beds of dice. Some of the water is ferruginous and smells offensively.

No other sections were noted in these beds, except a pit north of Claxby, showing dark shales, with a hard stony band 12 to 16 inches thick, and containing *Ammonites biplex*, *Ostrea deltoidea*, and small bivalves.

The appearance of the Kimeridge Clay, and the fact of its containing bands of inflammable shale, has led to the useless expenditure of large sums of money in boring for coal. A boring was made by Mr. Bogg in the neighbourhood of Donnington to a depth of 103 yards, with no further result than proving blue clay, argillaceous stone, and thin bands of inflammable schist (dice).* In 1819 an equally useless attempt to find coal was made at Woodhall; a shaft was sunk to a considerable depth, and a boring was carried to a total depth from the surface of 1,020 feet, with the result of tapping a saline spring, which has since proved of medicinal value.†

The bands of inflammable shale probably run through the whole district, but are very rarely seen from want of good sections. It may be mentioned here that similar beds occur in the Kimeridge Clay on the Dorsetshire coast, and have been mined by levels driven into the cliff.

A. S.

* See Appendix, p. 202.

† See Appendix, p. 205.

CHAPTER X.*

LOWER CRETACEOUS OR NEOCOMIAN ROCKS.

Classification.

The Neocomian Rocks run diagonally across the north-eastern corner of this Sheet at the foot of the Chalk escarpment. Though extending over wide areas in Sheet 84, they become restricted in the northern part of the present map to a very narrow strip, partly in consequence of a steady northerly attenuation of all the beds (*see* Plate), and partly through the increasing steepness of the slope in which they crop out. The various subdivisions succeed one another rapidly in this slope, yet each presents an easily recognisable feature.

Further north the Neocomian series is lost to view, partly through an unconformable overlap by the Upper Cretaceous rocks, but principally through the continued thinning away of the beds themselves. While thus unconformably overlapped, they themselves rest unconformably on the Kimeridge Clay. A glance at the map will show this better than a verbal description; the Neocomian beds, striking north-east, gradually approach the escarpment of Lower Oolites, which runs nearly due north and south, and, as they do so, overlap towards the north nearly the whole of the great thickness of Kimeridge Clay that underlies the neighbourhood of Horncastle in the south.

A detailed examination of the beds themselves confirms the opinion that these overlaps are attributable to erosion of the Neocomian beds in the one case, and of the Kimeridge Clay in the other, and not merely to a thinning out of these beds without unconformity. The Carstone is found to be made up very largely of the rolled and washed débris of the Neocomian clays, or, where the Carstone is missing (Sheet 86), the Red Chalk is found to contain fossiliferous nodules derived from the same source.† The base of the Neocomian beds again is found to be a nodule bed, with numerous rolled casts of fossils, many of which can be identified as having been derived from the Kimeridge Clay. In both cases, therefore, there is evidence of erosion having taken place. The beds intervening between these two lines of erosion, and known as the Speeton Series, form a very distinct group, distinguished both palæontologically and lithologically from the Carstone above and the Kimeridge Clay below.

In spite, however, of this evidence, it has been decided to retain the Carstone in the Neocomian group with the Speeton Series, principally because of the strong reasons for correlating the Carstone with a part of the Lower Greensand of the south-east of England, to which the name Upper Neocomian has been applied. The classification that has been, and is now proposed, will now be discussed.

* Written, except where otherwise noted, by Mr. A. Strahan.

† Notes on the Relations of the Lincolnshire Carstone, by A. Strahan. *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 489 and 491, 1886.

The most complete accounts of the Lincolnshire Neocomian that have yet appeared are by Professor Judd.* In the first of these communications, after describing the Red Chalk, he gives a detailed account of the beds under the following names :—

The upper ferruginous sands (probably representing the Norfolk Carstone).

The Tealby Series, consisting of sandy clay and limestone.

The Lower Sand and Sandstone.

He considers that the upper ferruginous sands are unconformably overlaid by the Hunstanton Limestone (the Red Chalk), his evidence of this being the fact that they, in common with the underlying beds, are overlapped towards the north by this rock ; the Tealby series is referred to the *Pecten cinctus* zone or Middle Neocomian of the Speeton section, the Lower Sand and Sandstone being of doubtful relationship.

In 1870 he correlated these subdivisions with those which have been made in other parts of the north of England and of northern Europe, and constructed a comparative table for the North of Europe, of which the two first columns are here given :—

—	YORKSHIRE.	LINCOLNSHIRE.
Gault (Albien, <i>D'Orb.</i>)	Hunstanton red-rock -	Hunstanton red-rock.
Unconformity.		
Upper Neocomian { (Aptien, <i>D'Orb.</i> ; Rhodanien and Aptien, <i>Rencv.</i> -	{ ? Fr. Black clays - 120 Dark blue clays "Cement beds" - 30	Upper Sands ?
Middle Neocomian { (Urgonien, <i>D'Orb.</i> ; Barrémien and Urgonien, Coq.) -	{ Dark blue clays, with few fossils 80 ("Zone of <i>Pecten cinctus</i> ." Blue clay, with fossils - 40 ("Ancyloceras beds." Clays, with septaria 30	"Tealby Series." Clays, limestones, and oolitic iron- stones, with many fossils.
Lower Neocomian (Néocomien, <i>D'Orb.</i> ; Valanginien and Néocomien, <i>Desor.</i>)	Blue clays - - - 100 ("Zone of <i>Am. speetonensis</i> ." Blue clays - - - 50 ("Zone of <i>Am. noricus</i> ." Blue pyritic clays - 50 ("Zone of <i>Am. asterianus</i> .")	Lower Sands and Sandstones ?
Tithonien, <i>Oppel.</i>	Unconformity.	
Jurassic - -	Portlandian Clays, &c. -	Kimeridge Clay.

* On the Strata which form the Base of the Lincolnshire Wolds. *Quart. Journ. Geol. Soc.*, 1867, vol. xxiii., pp. 227-251.

Additional observations on the Neocomian Strata of Yorkshire and Lincolnshire, with Notes on their relations to beds of the same age throughout Northern Europe. *Quart. Journ. Geol. Soc.*, 1870, vol. xxvi., pp. 326-347.

See also On the Speeton section, (*Quart. Journ. Geol. Soc.*, 1868, vol. xxiv., p. 218), where it is shown that the Blue Clay, 40 feet thick, and the clays with septaria are the zones of *Pecten cinctus*, and of *Ancyloceras* respectively.

It will be seen that the Upper Sands, though doubtfully correlated with the Upper Neocomian, are definitely included by Professor Judd with the Speeton beds in the Neocomian series, and that an unconformity is considered by him to exist between them and the Red Chalk.

In Lincolnshire, however, the Carstone contrasts strongly with the Tealby Series in lithological character, and in being completely unfossiliferous. While, moreover, there are no signs of erosion at the base of the Red Chalk, though its junction with the Upper Sands is repeatedly exposed, there is reason to think that considerable erosion of the Tealby Beds had taken place before the deposition of the Upper Sands, the evidence for this consisting in an overlap, and in the fact that the Upper Sands are made up principally of materials that appear to have been derived from the Neocomian clays.

The evidence of unconformity derived from overlap is not very satisfactory, inasmuch as the overlap takes place at more than one horizon, from the persistent thinning of all the beds northwards (*see* Plate); the following series of thicknesses, taken in order from south to north, will illustrate this:—

	South end of Wolds.	Tealby.	Orby.	Claxby.	Acre House.	Nettleton.	Audleby.	Melton Ross.	Elsham.
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Red Chalk	11	6	6	5	?	4	4	$\frac{1}{2}$	3-4
Upper Sands (or Carstone).	40	25	20	14	10	8	0	0	$\frac{1}{8}$
Tealby Beds	135	65	60 (about).	60	68	20-40	10	0	1-3
Lower Sands (or Spilsby Sandstone).	50	42	36 (about).	30	(?) 7*	35	15	9 (about).	10

As the Tealby Beds become reduced from 135 to 20 feet before the Carstone finally disappears, the argument for an unconformity as derived from an overlap is as applicable to the top of the Tealby Beds as to the top of the Upper Sands.

The palæontological evidence is of more significance. It may be at once stated that there is good reason for correlating the Lincolnshire with the Hunstanton Carstone. Lithologically the rock is identical, and in each case underlies the Red Chalk in a manner that leaves no doubt that it is the same bed. The age of the Hunstanton Carstone has been determined on the strength of certain fossils which occur in nodules near the base of the rock. These were first observed by Mr. Wiltshire, who correlated the portion of the Carstone in which they were found with the base of the

* Thickness as given in copy of the sinking journal of a shaft at the iron-mine; there appears to have been a mistake made, as the sand at the outcrop close by is of the normal thickness

English Lower Greensand.* The whole fauna, however, is regarded by Mr. Keeping as derived,† a conclusion which makes the Hunstanton Carstone later than those Neocomian rocks of Lincolnshire, in which the fossils are indigenous. The following is the list of specimens collected for the Woodwardian Museum, as given by Mr. Keeping :—*Perna Mulleti* (some of them derived, but some looking like natives); *Pleurotomaria*: *Ammonites Cornuelianus*, Forbes; *Ammonites Martini*, Forbes; *Ammonites Deshayssii*, Leym.; *Ammonites*, sp.? (allied to *Kænigi*); *Ammonites*, sp.?; *Ancyloceras gigas*, Sow.; *Ancyloceras* (tuberculated species); *Nautilus*, sp.

Further than this, in the Hunstanton Carstone there occur masses as large as cannon balls of a dark-coloured grit rock, containing a special fauna. From a careful study of the contained fossils (*op. cit.*, p. 34), and of their lithological character, Mr. Keeping concludes that these blocks “are all of Neocomian age, having been derived from a deposit closely connected with that of the Lower Neocomian sands of Lincolnshire, whose loose sandy materials being removed, the harder masses were left” (*op. cit.*, p. 37). The same rock is found in precisely similar condition in the Upware and Potton deposits. Specimens of the blocks from the Hunstanton Carstone may be seen in the Woodwardian Museum.

Reference has been made previously to the fact that the Lincolnshire Carstone is made up largely of the débris of Neocomian clays (Tealby Beds). It contains vast quantities of small well-rolled pebbles of a pale yellow or brown phosphate, with occasional lines of large nodules of similar substance containing Neocomian species. Among these the following have been noted by Mr. H. Keeping as occurring in pebbles in the Carstone at Claxby, about 5 feet below the base of the Red Chalk:—*Ammonites Deshayssii* (Leym.), *Am. biplex* (Sow.), *Requienia*? *Astarte* sp., *Corbula*, *Modiola*, *Myacites*, *Pholadomya*, *Cyprina*, *Teredo*. At Othby there were obtained during the present survey:—*Ammonites speetonensis* (?) four specimens, *Am. plicomphalus* (?) one specimen, *Lucina* (?), and others, and a gasteropod, all from well-rolled phosphate pebbles. The smaller materials of which the Carstone is composed, consist of quartz sand and small rounded quartz and Lydian-stone pebbles, such as occur in the Lower Sands and Sandstone; and of small flakes and grains of iron-oxide that appear to have been derived from the clays and iron ores of the Tealby Beds. The Lincolnshire and Norfolk Carstones have, therefore, this property in common, namely, of containing abundantly fragments, or washed débris, of some portion or other of the Speeton Series.

But in Norfolk the Carstone rests directly on the Kimeridge Clay, and must, therefore, be either considered to be partly representative of the Speeton Series, or this series must be

* *Quart. Journ. Geol. Soc.*, vol. xxv., p. 189, 1869.

† The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill, by Walter Keeping, M.A., F.G.S., 1883, p. 32.

supposed to be absent altogether. In discussing the first of these suppositions, it may be mentioned that there occurs a thin and impersistent band of clay in the Norfolk Carstone which at first sight might be taken to represent the Tealby Beds, the sand (or portion of Carstone) beneath it then representing the Lower Sands and Sandstone. But the accompanying table of comparative sections (*see* Plate) shows that the Tealby Beds are thickening in the direction of Hunstanton, when last seen in Lincolnshire. For example, from Nettleton to near Belchford, a distance of about $16\frac{1}{2}$ miles, these beds thicken from 30 to 135 feet, and in the Skegness boring (Sheet 84) had increased to 219 feet. It is, therefore, very improbable that they should thin out in the next 16 miles which separate Skegness from Hunstanton*. The details of the Norfolk section, moreover, do not correspond to the subdivisions which have been found so constant in the Tealby Beds in Lincolnshire.

On the second of these suppositions, namely, that the Speeton Series is wholly unrepresented in Norfolk,† an explanation of their absence is found in the evidence of unconformity between them and the Carstone that has been obtained in Lincolnshire. It must be supposed that the series was wholly denuded away from the Norfolk and adjoining areas of Bedfordshire and Cambridgeshire, before the Carstone was deposited. This implies that the denudation was greater on the south than the north side of the Wash, a conclusion which is borne out by a study of the included fragments of Neocomian Rocks that occur in the Carstone in different areas. In Lincolnshire these consist of nodules, &c. derived from the Tealby Beds; at Hunstanton of the same with the addition of boulders of Lower Neocomian Sandstone; and further south again of boulders of this sandstone, with the addition of a very large proportion of derived Kimeridge Clay fossils, and a smaller number of Portlandian and Oxford Clay forms, while a few only of Neocomian species are found. Similarly, towards the north of Lincolnshire, where the Red Chalk in the absence of the Carstone becomes conglomeratic (*see* Plate, sections 2 and 3), the fragments include specimens of older and older rocks, on approaching the area of upheaval which separated the Yorkshire and Lincolnshire basins in the Neocomian period, and in which older rocks are successively brought into contact with the base of the Upper Cretaceous beds.

The Hunstanton Carstone has been generally correlated with the Upware deposits and with the Neocomian rocks of Bedfordshire and Cambridgeshire. It follows then that these rocks also are later than the whole of the Speeton Series, and of the Tealby Beds of the Lincolnshire section. In the south of

* It is suggested by Mr. Jukes Browne that there may be unconformity at the base of the upper or Hunstanton Carstone, which would provide an explanation of the comparative thinness of the underlying clay in Norfolk. He considers the lower Norfolk sand to be more like the Spilsby Sandstone than the Carstone.

† It was stated as his opinion by Professor Judd, in the year 1869, that the Carstone of Norfolk does not represent the Tealby Beds. On the Red Chalk of Hunstanton, Wiltshire, *Quart. Journ. Geol. Soc.*, vol. xxv., p. 192 (Discussion).

England, however, there seems little doubt that there are equivalents of the upper portion at least of the Speeton Series. The fauna of the Atherfield Clay presents the closest analogy with the Upper Neocomian of Speeton according to Professor Judd, while the horizon of the Upware phosphate-beds, and of the lower beds of the Hunstanton Carstone is fixed by Mr. J. Mejer at that of a pebble-bed near the base of the Folkestone Beds. The supposed correlation with the south of England is added to the table given subsequently (p. 88).

We have now to face the difficulty of fossils of Neocomian species having been found *indigenous* in beds which, as we believe, have been made up from the waste of Neocomian rocks. The indigenous and derived faunas have been frequently confused, and are even now only partly distinguished, but enough has been done to prove that the Upware and other homotaxial deposits contain a large number of indigenous Neocomian (Aptien) species. We have, therefore, an unconformity between the newest Neocomian (Carstone) and the older Neocomian (or Speeton Series). In attempting to account for the presence of late Neocomian *derived* fossils in beds of late Neocomian age, Mr. Keeping supposes that "the ferruginous and phosphatic concretions were formed quickly after the formation of the rock, and, afterwards, some such alteration as a change of level, or a variation in the strength or direction of the ocean currents, caused the sediments to be torn away again, and the older organisms were redistributed as 'derived' fossils in immediately subsequent deposits" (*op. cit.*, p. 39). This, however, seems inadequate to account for the stratigraphical break of which evidence has been detailed above. The thickness of beds eroded away has undoubtedly been very considerable, and more than could be removed by a mere change in the direction of currents. It is necessary to suppose that the portion of the Neocomian (Speeton Series) sea-bed which extended over the south-eastern part of England was raised above the sea-level during late Neocomian times, but that it was again submerged and overspread by marine sands (Carstone, Upware Beds, &c.) before the fauna had had time to become radically changed.

The palæontological evidence, even in the face of this unconformity, points to the necessity of including the Norfolk Carstone, and therefore the same bed in Lincolnshire, in the same great group as the Speeton series as heretofore. But it would seem advisable to recognise more clearly the unconformity between them in a general classification than has yet been done. It is proposed, therefore, while retaining the name Speeton Series for the whole of the Yorkshire clays, to exclude the Carstone of Lincolnshire from this group. The name Tealby Beds will be applied to that portion of the series which is characteristically developed at the village of that name, and the Tealby Beds with the underlying Spilsby Sandstone (the Lower Sands of Professor Judd) will be correlated with the Speeton Series of Yorkshire. The names that are used for the various subdivisions, their classification and correlation with other districts are given in the following table :—

Yorkshire (Speeton).	Lincolnshire.	Norfolk.	Bedfordshire.	South Coast.
Absent	Carstone with derived Neocomian fauna.	Carstone with derived Neocomian fauna.	Sands with derived Oolitic and Neocomian fauna and indigenous Neocomian fauna.	Folkestone Beds with pebble-bed containing derived Oolitic fauna, and late indigenous Neocomian fauna.
Upper Middle Lower	<div> <div>Speeton Clay.</div> <div> <div>Tealby Beds</div> <div> <div>Tealby Limestone.</div> <div>Tealby Clay</div> <div>Claxby Ironstone.</div> <div>Spilsby Sandstone.</div> </div> </div> </div>	Absent.	Absent.	<div> <div>?</div> <div> <div>Sandgate Beds.</div> <div>Hythe Beds.</div> </div> </div> <div>Atherfield Clay.</div>

The Spilsby Sandstone.

This name has been applied to the lowest subdivision of the Neocomian in consequence of its occupying a large area in the neighbourhood of Spilsby in Sheet 84. In its unweathered form, as seen in certain large included masses, it is an extremely hard calcareous grit of a granite-grey colour, and with numerous fossils; through it are scattered small rounded pebbles of quartz, lydian stone, and others, but they occur more abundantly in certain pebbly bands. It is, however, exceptional to find the sandstone in its unweathered form; generally the calcareous cement has been removed, and partly replaced by iron-oxide, so that the rock occurs as a perfectly loose brown and white sand, containing great masses of friable brown sandstone. It is not uncommon to find a sand-pit and a sandstone quarry close together in the same bed, or even one pit combining both functions.

The tendency of the rock to weather in this manner has led to a large number of boulders having been derived from it from a very early period. The oldest known have been already alluded to as occurring in the later Neocomian rocks of Hunstanton and Upware; but a vast supply was derived from the same bed during the Glacial Period; they are found near South Willingham and Horncastle (pp. 131, 132), while boulders of a similar rock occur in Norfolk,* Suffolk,† and as far south as Herrimere near Ely.‡

* Mr. Clement Reid states that the Boulder Clay of West Norfolk contains a number of large masses ranging in size up to 6 feet and more in length, and composed of a hard iron-grey sandstone, usually with an abundance of small phosphatic nodules generally scattered throughout, and with many well-preserved fossils, of which *Pecten* is one of the commonest. The phosphates are dark-coloured and clearly derived. They resemble those derived from the Kimeridge Clay. A detailed account of some of the Norfolk boulders will be found in the Geological Survey Memoir on the Geology of the Country around Attleborough, by F. J. Bennett.

† Sowerby, *Mineral Conchology*, vol. i., p. 227.

‡ Ray Lankester, *Geol. Mag.* for 1870, p. 410. See also W. Keeping, On the Fossils and Palæontological Affinities of the Neocomian Deposits of Brickhill and Upware, pp. 32-37.

At its base the Spilsby Sandstone contains a bed of rolled phosphatic nodules, most of which can be identified as having been derived from the Kimeridge Clay *; the evidence for a line of erosion at this horizon has been previously given (p. 82).

The thickness of the subdivision varies from nearly 45 feet in the southern to about 30 feet in the northern part of the Sheet. Both to the north and to the south-east (Skegness) it is known to thin away; presumably it does so also to the east. It may therefore be regarded as a local shore-deposit.

Where it enters the map, a few miles north of Horncastle, the Spilsby Sandstone is at first deeply buried by an intensely chalky Boulder Clay, but the position of its boundaries, even under this covering, may be calculated pretty closely by the help of the three valleys near Asterby Grange, which have been cut through the Drift, and in the head of each of which the base of the Spilsby Sandstone may be traced for a short distance. Emerging finally from beneath the Drift in the valley of the Bain about Ranby Mill, the line runs a short distance up the Scamblesby valley, and thence up the valley of the Bain to beyond Donnington. The rock is seen in a sand-pit about one mile south of Goulsby on the Horncastle road to consist of soft brown and white or greenish sand, traversed by strong jointing running W. 35° S., perhaps with a small fault with a downthrow south-east. Near where the base crosses the stream at Asterby it occurs in a compacted form as a friable sandstone. After crossing the Bain near Donnington the base runs southward along the high ground, until it is lost to view under the mass of Drift which caps Benniworth Hill. An outlier emerges from beneath the Drift at a corresponding level on Market Stainton hill. The western limit of this outlier and the continuation of the boundary under the Benniworth Drift can only be guessed at. The sandstone is well exposed in Long Lane at the crossing of the stream from Stenigote, where the following beds are shown:—

	Ft.
Sandstone, grey above, with irregular brown patches - - -	9
Incontinuous band of pebbles about as large as split peas, with a fragment of the paddle of a <i>Pleiosaurus</i> (?), about	$\frac{1}{2}$
Grey, buff, and brown sand - - - - -	3 +

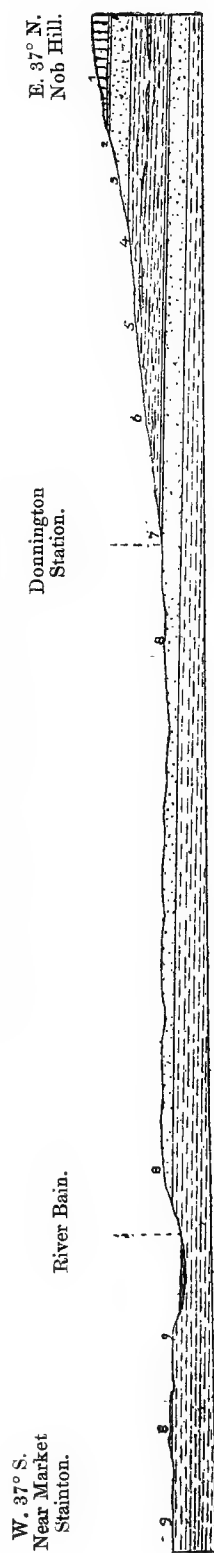
The bone when first observed was 9 inches long and 3 inches \times 2 inches at the one end, expanding to 4 inches \times 1 inch at the other. Being very fragile it fell to pieces during extraction and was partly lost.

Some of the best sections in the district are to be found near Donnington Station. The structure of the ground is illustrated by the accompanying section (Figure 4). It will be observed that the Spilsby Sandstone forms a gently undulating plain, the breadth of outcrop being greater than that of the Tealby Beds. Further north on the other hand, the Tealby Limestone, developing into a solid rock, has the broader outcrop, while that of the Spilsby Sandstone, though steep, becomes exceedingly narrow.

* This band of nodules is probably the same as that which is worked at the base of the Neocomian clays at Speeton.

FIG. 4.

Section of the Neocomian Rocks near Donnington.



Horizontal scale, 6 inches = 1 mile; vertical scale twice exaggerated.

Datum Line = Ordnance Datum.

1. Lower Chalk.
2. Red Chalk.
3. Carstone.
4. Upper Ironstone.
5. Tealby Limestone.

6. Tealby Clay.
7. Claxby Ironstone.
8. Spilsby Sandstone.
9. Kimeridge Clay.

The clearest exposures of the Spilsby Sandstone occur in the railway cuttings, west of Donnington.

The top bed is seen to a depth of 6 feet in a small sand-pit on the north side of the line, and a few yards only from a pit in the Tealby Clay; it consists of fine white sand with soft concretionary masses darker in colour, and surrounded by a vein of iron-oxide, and with wavy bands of more loamy sand and veins of iron-oxide; there are a few quartz fragments, but the mass is fine sharp sand. The same bed is seen in the first railway cutting west of Donnington Station, where the section is as below:—

Fine white sand	-	-	-	-	-	Fr.
Passing down into similar but more coherent sand, brown in places, and containing hard masses cemented by iron-oxide	-	-	-	-	-	6
Hard pebbly band containing numerous pebbles of quartzite, hornstone, decomposed felspar or limestone, slate, &c., about as large as peas, and with numerous cavities formed by the weathering out of <i>Belemnites</i> (<i>B. lateralis</i> , Phil.), and some fragments of silicified wood	-	-	-	-	-	13
Harder "iron-bound" brown sandstone with scattered pebbles and numerous impressions of fossils, principally <i>Pecten</i> , with an occasional <i>Ammonite</i> , seen here and close by to be	-	-	-	-	-	14 +
						<hr/> 33½ + <hr/>

At a short distance from the line on the north side there is an outlier of the Claxby Ironstone, at 2 or 3 feet height above the top of the cutting. Traced for 50 yards westwards, the pebble-bed mentioned above becomes irregular and apparently splits. It is underlain by a greenish sand passing down into a soft brown sandstone with very numerous impressions of *Pecten*. The cavities formed by the weathering out of the shells are usually lined with iron-oxide.

About 6 feet below the pebble band there occur some remarkable examples of concretionary action. In a brown friable sandstone of the usual character there runs a thin line of hardish grey sandstone enclosing a space about 3 feet × 2 feet, filled with a perfectly incoherent ashy-grey sand; in this sand is embedded an irregularly shaped mass of very hard grey quartz-sandstone slightly calcareous. The rock is traversed by two or three lines of fossil impressions; and it may be easily seen that these run through the outer casing, the soft ashy sand, and the hard calcareous core without any deviation, proving that the particles of sand retain their original position, the peculiar structure resulting merely from a rearrangement of the cementing agents. The internal core of grey calcareous sandstone appears to represent the unweathered condition of the rock. It contains fossils in a perfect state of preservation, and resembles the unweathered specimens in which perfectly preserved fossils are got elsewhere. The ashy-grey sand is the same rock, with the loss of the carbonate of lime, and consequently of the coherence. The enclosing vein of grey sandstone is not calcareous, but is probably hardened by a ferruginous cement. It is very thin, but stands out prominently from the crumbling away of the softer material through which it runs. Two or three of these structures occur, and the rock containing them has scattered through it several small round or twig-shaped concretions of iron-oxide. It is probable that the whole of the Spilsby Sandstone originally occurred in the form of the hard calcareous sandstone of which these cores consist, and that its present friable and iron-stained condition is purely the result of subsequent chemical action. The sandstone is overlaid by the Claxby Ironstone, a ferruginous clay, crowded with oolitic grains of iron-oxide. The effect of water percolating from such a bed through a calcareous sandstone would be to replace the carbonate of lime by carbonate of iron. Subsequent exposure would cause the conversion of the carbonate of iron to a peroxide or protoxide according to local circumstances, both of which ores have a known habit of collecting into nodules and concretions.

Crossing the Bain to the west, the next cutting is in a white and yellow sand capped by flaky brown fine-grained sandstone, weathering into cylin-

drical fragments; the white and yellow sand contains harder masses in which impressions of *Pecten* are abundant. The base of the Spilsby Sandstone is here only a few feet below the level of the rails, and a few of the usual rolled phosphatic nodules and phosphatic casts derived from the Kimeridge Clay may be picked up in the soil.

The next cutting westward has been described and figured by Mr. H. Keeping.* It shows about 20 feet of the Spilsby Sandstone capped by 9 feet of the Claxby Ironstone. About 4 feet from the top of the sand there runs a yellowish stony band containing fossils, now much broken up by weathering.

The last cutting before entering that which leads to the tunnel shows:—

				Ft.	In.
Ironstone, about	-	-	-	3	0
Green clay	-	-	-	1	3
White sand, fretted	-	-	-	7	0
Greenish sand	-	-	-	8	0+

The sections in the approaches to the tunnel are now obscured by the slipping down of Drift. There was formerly an exposure of the junction of the Spilsby Sandstone and Kimeridge Clay, a few hundred yards east of South Willingham Station, as described and figured by Mr. Keeping (p. 241). He states that "here the greenish sands, where they lie on the flaggy Kimeridge Shales, contain at their base a line of phosphatic nodules."

About 500 yards east-south-east from South Willingham Station is a sand-pit where sand has been dug for use in the neighbouring brick-yard. It shows white sand, with a few scattered grains of quartz as large as peas. The sand is overlaid by 3 to 4 feet of Boulder Clay (p. 135).

A sandstone quarry 150 yards south-south-east of Donnington Windmill shows:—

				Ft.	In.
Yellow and brown sand	-	-	-	0	8
Do.	with pebbles and <i>Belemnites</i>	-	-	1	1
Do.	sandstone	-	-	4	0
Brown sandstone with <i>Pecten</i> abundant	-	-	-	1	0
Soft yellow sandstone	-	-	-	2	0+
				8	9

Near the head of the valley running up to the wold-foot the concretionary structure in the Spilsby Sandstone takes the form of vertical, oval, or round cylinders 3 to 6 feet in diameter, and 4 to 5 feet high. The cylinders are formed of six or eight concentric rings, and stick up through the grass like the stumps of hollow trees. The sandstone is pale yellow or white.

South-east of Sixhills, phosphatic nodules ranging up to 2" × 1" × 1" may be picked up in fair abundance in the soil of the Kimeridge Clay just below the base of the Spilsby Sandstone. Their shape is irregular, and a few only are casts of fossils.

One mile south of the "Heneage Arms" (as marked on the map) there is a quarry showing rich brown sandstone to a depth of more than 12 feet. Some small black pebbles and a very few small phosphatic nodules are scattered through the rock. The surface of the rock where acted upon by soil-water is bleached and incoherent, the junction of the loose sand and the coherent brown sandstone being uneven, but quite sharp. In the heart of the brown sandstone there occur two hollows about two feet long by three-quarters of a foot deep, filled with a perfectly loose ashy-grey sand similar to that which filled the hollows in the sandstone near Donnington (p. 91), but without the hard core. The stone from this quarry was employed in building Withcall Church and the Railway Bridge at South Willingham; it is said to harden with exposure.

About 300 yards to the south-south-west there is a sand-pit in the same bed, which, though of nearly the same colour, is here so soft as to be dug

* On some Sections of Lincolnshire Neocomian. *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 239-244. 1882.

with a spade. Some patches of loose ashy-grey sand may be seen in the brown sand.

At Sixhills the Spilsby Sandstone is lost sight of for a short distance beneath a spur of Boulder Clay, but north of this village may be followed without further interruption beyond the limits of the sheet. On the south side of the Louth and Lincoln road near North Willingham there is a large pit showing 28 feet of white and greenish sand, soft in some places and hard in others, and mottled in the lower part with brown. Some of the harder masses are grey and resemble the grey calcareous cores found in the cavities at Donnington (p. 91), while others are brown. The soil at the top is crowded with pebbles of white quartz and banded hornstone, apparently washed down from a pebble bed above. The pit is traversed by strong joints running north-north-west, and it is interesting to note that the staining of the rock by iron oxide, and the arrangement of this mineral in concentric layers, has been influenced by the joints.

Due north of this pit, and on the opposite side of a small valley, a shoulder of Spilsby Sandstone has been cut through by a farm-road. The sandstone is grey and very hard, and weathers into spheres varying in size from a pea to a walnut, and closely crowded together. In the upper part it contains a band of pebbles of white quartz and dark hornstone, about as large as beans. The rock is traversed by an irregular joint running about north-north-west and lined with calc-spar, with pockets of the same mineral. Some of the spheres referred to above contain a core of this spar, the hardness and tendency to weather into this form being apparently due to its presence. This botryoidal weathering is of frequent occurrence in the Spilsby Sandstone, especially in the blocks which occur in the Drift (Imber Hill, &c.), but in no other instance has the calc-spar been in sufficient bulk to be extracted.

Derived Fossils of the Spilsby Sandstone.

Reference has been already made to the nodule-bed which occurs at the base of the Spilsby Sandstone. It is not now anywhere exposed *in situ*, but the pebbles derived from it may be picked up in the soil in most places along the top of the Kimeridge Clay. They are dense, greyish-blue on the outside, and darker inside. An analysis by Mr. M. Staniland, junior, proves them to contain 21·37 per cent. of phosphoric acid, and 29·91 per cent. of calcium oxide, with carbonic acid and sesquioxide of iron, 37·94 per cent. being insoluble; or, in a second analysis, loss on ignition 4 per cent., phosphate of lime 46·65 per cent., carbonate of lime 8·21 per cent.

Many of them are the internal casts of fossils, much water-worn and scarcely recognisable. The following have been noticed:—

Ammonites biplex, Sow. (abundant), and others, *Myacites* (abundant), *Thracia* (abundant), *Cucullæa*, *Pectunculus*, *Arca*, *Lima*, *Lucina portlandica* (?), *Pleurotomaria*, *Waldheimia*, and *Terebratula ovoides*, Sow. Mr. Keeping notes also *Cardium* and *Astarte* (?).

In most cases it is impossible to identify the species, but it may be mentioned that the *Myacites* is like both *M. recurva* of the Kimeridge Clay and *Panopæa neocomiensis*, Leym. of the Neocomian; the *Thracia* equally resembles *T. depressa* of the Kimeridge Clay* and *T. Phillipsii* of the Neocomian; the *Wald-*

* It especially resembles a variety of *T. depressa* from the Kimeridge Clay of Market Rasen.

heimia is closely allied to *W. lampas*, Sow., of the Coral Rag of Dorsetshire, but also resembles *W. Woodwardii*, Walker, of the Neocomian; while one of the *Ammonites* (of which a single very imperfect specimen has been found) is very like *Ammonites speetonensis*, Y. & B., of the Neocomian. The general character, however, of the nodules, and the abundance of certain forms (e.g., *Ammonites biplex*) points to their having been derived from the Kimeridge Clay. The single specimen of *Ammonites speetonensis* (?) is the only fossil which has not yet been matched in the Upper Oolite, and, being a rolled and imperfect cast, cannot be regarded as of much importance. To admit any characteristic Neocomian forms in the above list would be to suppose the former existence of Neocomian beds in this district, older than any of those that are now represented.

It is, moreover, in accordance with the stratigraphical evidence that a line of erosion should be found at this horizon. As previously mentioned (p. 82), the Spilsby Sandstone overlaps the Kimeridge Clay northwards with a strong appearance of unconformity, and the erosion accompanying an unconformable overlap would naturally result in the removal of the mass of the clay and the washing out of the only hard portions to form a basement conglomerate to the succeeding formation. It may be mentioned that a bed of coprolites having a strong lithological likeness to these nodules is worked at the base of the Neocomian at Speeton in Yorkshire.

A list of the indigenous fossils of the Spilsby Sandstone is given on p. 101.

The Tealby Beds.

The Spilsby Sandstone is overlaid quite conformably by the Tealby Beds, consisting in descending order of:—

Tealby Beds	{	Tealby Limestone	{	Upper Ironstone and clay.
			{	Limestone (= the " Roach "
			{	Ironstone of Sheet 84).
			{	
				Tealby Clay.
				Claxby Ironstone.

Claxby Ironstone.

This is a yellow ferruginous clay packed with minute spherical oolitic grains of iron oxide, and very fossiliferous. It rests with a generally sharp base on the Spilsby Sandstone, but passes quite gradually up into the less ferruginous mass of the Tealby Clay. The most southerly occurrence of this bed yet known is at Hundleby (Sheet 84); from here northwards traces of it may be seen in the soil at many places, but not in such profusion as to justify its being coloured on the map along the whole length of outcrop. Moreover, the presence of similar grains of iron-oxide in the soil of the Tealby Clay at higher horizons makes it doubtful whether the Claxby Ironstone is sufficiently distinct in the southern part of Sheet 83 to be worth a dividing line.

But at Donnington the bed becomes very well marked, and so continues northwards to Claxby Iron Mine (Sheet 86), where it is extracted and sent to Leeds to be smelted in admixture with the argillaceous ores of the Coal-measures. It is described here by Professor Judd as being an eminently calcareous ore, frequently exhibiting veins of beautifully crystallized calc-spar; it yields on analysis from 28 to 33 per cent. of metallic iron; in many places it appears to have undergone a certain amount of dehydration, and exhibits irregular patches of dull reddish tints.* An analysis and microscopic examination of the oolitic grains by Mr. M. Staniland, junior, gave the following results:—

Silica	-	-	-	5.34
Sesquioxide of iron	-	-	-	76.76 (or about 53.73 per cent. of metallic iron).
Moisture	-	-	-	16.17
				98.27

The grains are almost perfectly spherical, polished, and about the size of millet seed. They are made up of alternating concentric layers of clear silica and opaque hydrated sesquioxide of iron. The clay matrix in which they were imbedded was found to contain silica, alumina (but no lime), sesquioxide of iron, and a trace of phosphoric acid.

The best exposures of this bed in the present sheet are in the railway cuttings at Benniworth Haven, previously alluded to (p. 92). One of the cuttings is described by Mr. H. Keeping† as showing about 9 feet of the ironstone, consisting of three divisions: (1) the better bed at the base, (2) a lighter-coloured argillaceous bed with cuboidal fracture, (3) brown crumbling stone at the top. From it he obtained a richer suite of fossils than from anywhere else in the district (p. 102); they were best preserved near the base, but now are much broken by weather. Fragments of *Exogyra sinuata*, Sow., *Lima*, sp., *Cucullæa Gabrielis*, Leym., *Trigonia nodosa*, Sow., and *Belemnites lateralis*, Phil., are abundant.

The last cutting westwards before entering that which forms the approach to the tunnel affords a very clear view of the junction of the Ironstone and the Spilsby Sandstone; the section is given on p. 92.

In the approach to the tunnel, fragments of the same bed may be seen; but the bed itself, if it occurs here, is concealed by slips of Drift.

This bed crops out under Donnington Station between the brick-pit in the Tealby Clay and the sand-pit in the Spilsby Sandstone, and may be seen in the ditches by the side of the road to Donnington, and again on the west side of the Bain by Donnington Windmill.

Between Hainton and Claxby there are no clear exposures of the Ironstone, though its outcrop may be followed with ease, owing to its occurring at the line of junction of two beds so distinct (lithologically) as the Tealby Clay and Spilsby Sandstone. Everywhere along this line the soil is found to be crowded with the spherical grains of iron oxide. North of Tealby several shafts have been sunk, in the hope of finding the bed to be of commercial value; one of these, said to be very deep, is close to a quarry in the Tealby Limestone on the west side of the ravine near Risby Hall. East of Otby a shaft was commenced in the white chalk, but abandoned; another, about $2\frac{1}{2}$ furlongs south of Otby, started in the Carstone and reached a depth of about 100 feet. About the same distance north-east of Otby are traces of levels having been driven into the bill-side, but apparently in a higher bed of ironstone, as

* *Quart. Journ. Geol. Soc.*, vol. xxvi., p. 330.

†

Do.

vol. xxxviii., p. 243.

hereafter mentioned. There have been trials on the west side also of the Othby Valley, apparently in slipped masses of the Tealby Clay. All the shafts have been abandoned, and have most of them fallen in. South of the road leading up to Normanby-on-the-Wold from Claxby there is a slipped mass of the Ironstone in which fossils are very abundant, but broken up by weather. The Ironstone, a brown decomposed rock, packed with oolitic grains of iron oxide, is overlaid by a little grey clay with phosphatic concretions, presumably the base of the Tealby Clay.

The lists of fossils from the Claxby Ironstone is given subsequently, pp. 102-104.

Tealby Clay and Limestone.

The Tealby Clay attains its greatest development at the south end of the Wolds in Sheet 84, but is still of great thickness at Cawke well and Scamblesby, where it enters Sheet 83. The Skegness boring (Sheet 84) encountered 219 feet of clay below the Carstone, and though a portion of this must be correlated with a ferruginous limestone that corresponds to the Tealby Limestone, yet the equivalent of the Tealby Clay alone must exceed 150 feet in thickness. At the outcrop further west, the thickness appears to be a little over 100 feet, and this is nearly maintained as far as the Scamblesby outlier, where the top of the subdivision is clearly defined by the feature of the ferruginous limestone. North of this, at the foot of the wold, the attenuation becomes very apparent, though it is difficult to assign an exact thickness to the clay from the fact of the horizon of the Tealby Limestone being extremely ill-defined as hereafter mentioned. The thickness at Donnington was estimated by Mr. Keeping at 30 feet; at Tealby it is about 26-28 feet; but at Acre House Mine Shaft it has expanded again to 40 feet. But little importance can be attached to these measurements, inasmuch as the base of the Tealby Limestone probably does not follow the same horizon, owing to the wedging of beds of limestone into the clay. The measurements of the whole group of the Tealby beds, which are more trustworthy, show a constant attenuation along the outcrop from south-east to north-west. The following measurements (most of which were made by aneroid) will illustrate this:—

—	Skegness Boring.	South End of Wolds.	Tealby.	Othby.	Acre House Mine Shaft.
Thickness of Tealby Beds.	Fr. 219½	Fr. 135	Fr. 65	Fr. 60 about.	Fr. 68 about.

—	West of Nettleton Lodge.	East of Nettleton Lodge.	½ mile east of preceding.	Nettleton Grange.	Andleby.
Thickness of Tealby Beds.	Fr. 50	Fr. 40	Fr. 20	Fr. 23 about.	Fr. 10

The Tealby Clay is generally a tough blue clay, considerably paler in tint than the Kimeridge Clay, and with less apparent bedding and lamination; it weathers to a cold and very stubborn yellow clay soil. In the northern part it is of little agricultural importance from the narrowness of its outcrop, though the indications of its presence are clearly marked in the soil and in the abundance of fragments of *Exogyra sinuata* that are turned up by the plough. But about Scamblesby it runs down the long slopes of the hills for a considerable distance, ending off in a feather-edge on the nearly level surface of the Spilsby Sandstone.

In proceeding, as before, from south to north along the outcrop, we first come to an old clay-pit, now overgrown, on the west side of Imber Hill, but the best exposure in the district is in the brick-pit at Donnington Station. The clay is pale-blue or grey, and very homogeneous. It contains a large number of flattish oval phosphatic nodules, black inside, and weathering pale yellow. Most of them are traversed by shrinkage cracks, and many of them contain a fragment of a crustacean. The most abundant fossils are *Exogyra sinuata*, *Serpula*, and *Belemnites*; one specimen also of the *Perna Mulleti*, Desh., with the large *Exogyra* attached, was found. The workmen had also picked out *Ammonites speetonensis*, Y. & B., *A. speetonensis*, Y. & B. var. *venustus*, Phil., *A. speetonensis*, Y. & B. var. *concinuus*, Phil., and *Crioceras Duvalii*, Lév. The same clay is exposed in the shallow cutting east of Donnington Station.

North of this point the outcrop of the clay rapidly diminishes in width; the overlying limestone, as it increases in solidity, beginning to form a broader terrace, and leaving a steep and narrow belt only for the outcrop of the clay. The division between the two is at first extremely indefinite, and only becomes marked to the north of the Willingham Valley. The Tealby clay appears to extend up the valley of the Bain for a mile at least above Brough. There is an old brick-kiln near the junction of the Calsthorpe stream, showing pale-blue laminated clay weathering yellow, which in the upper side of the pit and in the slope above is overlaid by the intensely chalky Drift.

Near North Willingham the narrow outcrop of this clay is marked by the stiff yellow soil with abundant fragments of *Exogyra sinuata* before alluded to.

In the Oby valley, and in the hill-side above Claxby, the position of nearly all the Neocomian outcrops has been shifted by landslips. The slip commences through the crumbling away of the incoherent parts of the Spilsby Sandstone; the Ironstone and Tealby Clay then bend over and spread themselves over the whole of the outcrop of the sandstone, while blocks of limestone are brought down by the sliding surface far below the position of their outcrop. The process is assisted by the issue of springs from the base of the limestone and of the Carstone. At the Castle Farm, near Tealby, there is a small clay pit, apparently on the outcrop of the Spilsby Sandstone, but probably in a slipped mass of Tealby Clay. Reference has previously been made to the grey clay with phosphatic nodules (Tealby Clay) that has slipped down with the ironstone near Normanby. Though so much reduced in thickness here, this subdivision is clearly recognisable for several miles along the escarpment.

The Tealby Limestone, which becomes so important a rock in the northern part of this sheet, is completely lost to view in the south, between Donnington and Cawkwell. It has been elsewhere shown (Explanation of Sheet 84) that at the south end of the Wolds the Tealby Clay is capped by a hard calcareous ironstone or ferruginous limestone, a rock so hard as to form plateaux with steep well-defined edges on the clay hills (Hoe Hill and Fulleby Hill) and a prominent feature in the Wold escarpment. Traced northwards this rock enters Sheet 83 south of Scamblesby,

but is soon lost to view beneath the Boulder Clay. In the Wold escarpment close by it is not so clearly seen, and a little further north completely disappears, there being no feature even to mark its position. But near Stenigote, along the same line of outcrop, there may be picked up small fragments of Tealby Limestone, which become steadily more abundant northwards until near Donnington, Biscathorpe, and Gayton they are sufficiently numerous to be dug out for building. Near Donnington the first exposure of limestone in place occurs. The fact of the Tealby Limestone of the north making its appearance at the same horizon as the ferruginous limestone of the south, and so near where the latter disappears, is considered sufficient reason for correlating the two, though they cannot be traced on continuously; the ferruginous limestone is often not unlike the Tealby Limestone. The position of the ferruginous limestone is shown in Section 9 of the Plate.

The Tealby Limestone and its equivalent in the south are overlaid by a soft yellow roach, with numerous grains of iron oxide similar to those in Claxby Ironstone. The notices of the occurrences of this bed, which will be referred to as the Upper Ironstone, will now be taken with those of the Tealby Limestone.

The Upper Ironstone is first seen by the side of the Louth and Horncastle road on Cawkwell Hill, but from thence northwards is nearly everywhere hidden by a down-wash of the Carstone. The underlying Tealby Limestone is first clearly recognised in the road from Welsdale Bottom to Donnington, though a few fragments may be picked up considerably further south. Near Biscathorpe there is similar evidence of its presence. Along all this hill-side loose blocks have been dug out of the soil for building purposes, the bed probably occurring in lenticular masses, as shown in Figure 4 (p. 90). The stone, used in the farm-buildings opposite Gayton-le-Wold Church, was dug out of a yellow clay close by. Mr. Jukes-Browne remarks, that higher up the valley, by the next farmstead, larger blocks of the same grey limestone lie near the bridge. South of this the watercourse cuts through a bed of soft crumbling oolitic ironstone (Upper Ironstone), brownish above and greenish below, but quite decomposed. This appears to be succeeded by clay and by the Carstone, which is very thin round Welsdale Bottom.

On the south side of Brough the limestone has been dug out in several small pits, now nearly all obscured by overgrowth; some stones with small oolitic grains of iron oxide may be picked up.

Three-quarters of a mile north-north-west of the "Heneage Arms" (as named on the map), there is an old lime-kiln in the Tealby Limestone, showing:—

	Ft.
Soft yellow flaky and earthy limestone, with oolitic grains of iron oxide, much weathered	9
Hard blue limestone	2 +
	<hr/> 11 <hr/>

Hemipneustes ? sp., *Ostrea frons*, Park., *Pecten cinctus*, Sow., *P. orbicularis* ? Sow., *Thetis* ? sp., *Panopæa neocomiensis*, Leym., *P. ovalis*, Sow., *Trigonia*, sp., and *Belemnites lateralis*, Phil. were obtained here. The shells of the *Pecten cinctus* were coated with *Serpulæ* on both valves.

From here northwards the feature produced by the limestone is easy to follow, as might be expected from the above section. Professor Judd remarks, that the limestone forms a terrace, which, being cut through by the numerous streams flowing westward from the watershed, extends in a number of prominent spurs from the edge of the Chalk-wold.

The next section is obtained in an old kiln one mile north-north-east of Sixhills; it shows :—

	Ft	In.
Brown soil, with few oolitic grains of iron oxide	-	2 0
Pale blue sandy limestone	-	1 0
Green clay, full of comminuted shells	-	0 4
Limestone, variable, about	-	1 3
Green clay, as above	-	0 6
Limestone, variable	-	1 0
Pale green clay, with comminuted shells and nodules of iron ore	-	1 6
Limestone, about	-	0 10
Pale green clay	-	1 0
Limestone	-	1 0
Green clay	-	1 2
Limestone	-	1 0
	<hr/>	<hr/>
	12	7

The nodules in the green clay are brown outside, with an internal core of yellow hydrated sesquioxide. There occur also twig-shaped and irregular concretions, hardish and yellow, that are probably phosphatic, and large spherical or oval concretions, about 5" in diameter, traversed by thin veins of calc-spar, like septaria; they are dark, sometimes almost black, and contain fossils which are difficult of extraction. The fossils in this pit are not abundant; the most common are fragments of a large *Exogyra*, *Belemnites lateralis*, Phil., and a small *Pecten orbicularis*? *Pecten cinctus*, Sow., also occurs.

Near South Willingham, *Cardium subhilianum*? Leym., *Cyprina*, sp., *Panopæa*? sp., and *Trigonia*, sp., were obtained.

A large pit on the south side of the Louth and Market Rasen road, exposes the following beds:—

	Ft.	In.
Much weathered flaky limestone, with <i>Pecten cinctus</i> , Sow., and ? plant-remains	-	0 6
Soft greenish earth with band of fossils, <i>Exogyra sinuata</i> , Sow., <i>Pecten orbicularis</i> , Sow., <i>Belemnites</i> , spec., and vertebra of an Elasmobranch	-	0 10
Bands of limestone with roach-partings	-	6 0 +
	<hr/>	<hr/>
	7	4

A second pit further west, and on the north side of the road, shows 6 feet of hard limestone in beds of 1 to 1½ feet with greenish clay-partings of about 6 inches thickness. One of these two pits is referred to by Professor Judd; the section as seen by him differs in details from those given above, as might be expected after the lapse of several years. He noted a sandy bluish-grey clay, 4 feet thick, near the top of the pit. In it there occurred a remarkable layer of fossils, consisting of numerous specimens of *Pecten cinctus*, Sow., mingled with *Exogyra sinuata*, Sow., and numerous other fossils, among which *Belemnites semicanaliculatus*, Blain., *Ostrea frons*, Park., *Pecten orbicularis*, Sow., and *Rhynchonella parvirostris*, Sow., were perhaps the most abundant. He remarked also that the specimens of *Pecten cinctus*, which were from 9 to 12 inches in diameter, were always found lying on their lowest or most convex side, and that their upper valves, as well as the edge of their lower ones, were not unfrequently covered, to the thickness of 2 inches or even more, with a tangled mass composed of *Serpulæ* of several species. Other shells, as *Exogyra*, are frequently attached to these gigantic *Pectens*.

East-south-east of Walesby Church, on the north side of the Risby Hall ravine, there is a pit in the Tealby Limestone, showing:—

	Ft.
Grey and brown clay, with bands of rotten limestone	6
Limestone, in beds from 1 to 2 feet thick, with grey clay partings	6 +
	<hr/> 12 <hr/>

In a lower part of the excavation, limestone is seen in beds of $\frac{1}{2}$ to 1 foot thick, with grey clay partings, this thin-bedded rock apparently forming a passage down into the Tealby clay. The sides of the pit have lately fallen in, making the section obscure.

From this point there are no good sections in the Tealby Limestone for a long distance, but the overlying Upper Ironstone is well seen in two or three places on the east side of the Othby valley. The sections occur at the foot of the steep banks formed by the outcrop of the Carstone, west and south-west of the "Barn," marked on the map. The following continuous section was made up from these exposures:—

	Ft.	In.
Carstone (for details see p. 112)	20	6
Upper Ironstone	Yellow ferruginous clay, with occasional concretions	0 9
	Dark ashy-grey clay-grit with phosphatic concretions (formed in place)	4 0
	Grey clay, with scattered oolitic grains of iron oxide	3 0
	Darker clay, with oolitic grains very abundant	3 0
	Pebbly band, containing lumps of black oxide of iron and nodules, with small pebbles of quartz included, embedded in a matrix of grey ferruginous clay	0 6
	Grey clay with oolitic grains of iron oxide very abundant in parts	9 0
	Brown iron-shot stone-band, with bands of yellow greasy clay (about)	5 0
	Tealby Limestone (approximate position of top of).	
	<hr/> 45 <hr/>	9 <hr/>

It is in this Upper Ironstone that some old levels have been driven about a quarter of a mile east-north-east of Othby; they have been long since abandoned and are now fallen in. The ore is stated to be not worth extraction.

This same bed is seen in a pit half a mile north-north-west of Normanby Church, as follows:—

	Ft.	In.
Upper Ironstone	Brown clay packed with oolitic grains of iron oxide	5 0
	Grey shale (about)	0 4
	Brown rocky clay packed with oolitic grains	1 6
	Friable brown stone with fossils (perhaps a weathered limestone)	2 0 +
	<hr/> 8 <hr/>	10 <hr/>

Nearer to the church, and at a slightly lower level, there is a pit for road-metal in the Tealby Limestone, which exposes :—

		Ft.	In.
Upper Ironstone	Light yellowish-brown clay, with oolitic grains of iron oxide	2	0
	Reddish clay with oolitic grains	0	6
	Yellowish-green clay with oolitic grains	0	4
	Yellowish brown clay, with grey bands	2	2
	Friable brown stone (weathered limestone)	2	0
Tealby Limestone	Shaly parting, with <i>Exogyra sinuata</i> abundant at base	0	8
	Hard limestone, with spar-lined joints	2	0
	Shaly parting, with <i>Belemnites</i>	0	6
	Hard limestone	0	6
	Shaly parting	0	3
	Hard limestone	0	10
	Shaly parting	0	2
	Hard limestone	3	0
	Hard limestone, in beds of 4 to 8 inches, with numerous partings	4	0+
		18	11

In all this part of the escarpment a double feature is noticeable, the upper being due to the outcrop of the Tealby Limestone (the total thickness of which may be about 15 feet), and forming the brow of the hill; the lower feature marking the outcrop of the Spilsby Sandstone. From the brow of the escarpment the ground rises eastward in a gentle slope formed by the outcrops of the Upper Ironstone, the Carstone, and the Red and White Chalk.

In the extensive inlier of Neocomian rocks that extends from Stainton-le-Hole to Thorpe-le-Mire, the beds have been cut into to the surface of the Tealby Limestone. The limestone is seen in the bottom of a valley about three-quarters of a mile west-north-west of Thorpe, in two small pits, as described subsequently. The overlying ironstone is nearly everywhere concealed by down-wash from the Carstone, and by the peaty growth that marks the outburst of springs from its base; ferruginous clay with oolitic iron grains may be distinguished in the soil about three-quarters of a mile south-south-east of Stainton Church.

FOSSILS OF THE NEOCOMIAN ROCKS.

Indigenous Fossils of the Spilsby Sandstone.

The following fossils have been observed by Messrs. W. and H. Keeping,* as occurring in place in the Spilsby Sandstone, chiefly

* The Fossils, &c. of Upware and Brickhill, p. 64, and *Quart. Journ. Geol. Soc.*, vol. xxxviii., p. 241.

about Willingham and Claxby. Lists of the specimens obtained further south during the survey are given in the Memoir on Sheet 84, p. 140.

<i>Belemnites</i> , sp.	<i>Trigonia Keepingi</i> , Lyc.
<i>Ammonites Kœnigi</i> , Sow.	„ <i>robinaldina</i> , D'Orb.
„ <i>mutabilis</i> , Sow.	„ <i>tealbiensis</i> , Lyc.
„ <i>plicomphalus</i> , Sow.	„ (dædaloid form).
„ <i>multiplicatus</i> , Roem ?	„ <i>ingens</i> , Lyc.
<i>Chemnitzia</i> spec.	„ <i>alæformis</i> , Sow. var.
<i>Phasianella</i> „	<i>Inoceramus</i> spec. ?
<i>Pleurotomaria</i> „	<i>Avicula</i> „
<i>Trochus</i> „	<i>Arca</i> „
<i>Crepidula</i> „	<i>Tellina</i> „
<i>Pileopsis</i> „	<i>Lucina</i> „
<i>Natica</i> „	<i>Cytheræa</i> „
<i>Pecten cottaldinus</i> , D'Orb.	<i>Thetis</i> „
„ <i>orbicularis</i> , Sow. var. <i>agnus</i> ,	<i>Astarte</i> „
Keep.	<i>Myacites</i> „
<i>Cucullæa donningtonensis</i> , Keep. MSS.	<i>Pholadomya</i> „
„ <i>errans</i> , Keep.	<i>Lithodomus</i> , &c.
<i>Cardium subhylanum</i> , Leym.	<i>Lima tombeckiana</i> , D'Orb.

During the survey the following have been noted :—Fossil wood, *Pecten cinctus*, Sow., *P. orbicularis*, Sow., vertebra of a fish, *Belemnites lateralis*, Phil., and the paddle of a *Pleiosaurus* (?).

The following list of fossils from the Claxby Ironstone is taken from Mr. H. Keeping's paper* :—

Fossils of the Claxby Ironstone.

<i>Belemnites lateralis</i> , Phil.	<i>Ostrea frons</i> , Park., var. <i>macroptera</i> ,
„ <i>quadratus</i> , Röm.	Sow.
„ spec. ?	<i>Exogyra sinuata</i> , Sow.
<i>Ammonites noricus</i> , Schl.	„ <i>tombeckiana</i> , D'Orb.
„ <i>plicomphalus</i> , Sow., and	<i>Pecten cinctus</i> , Sow.
others.	„ <i>striato-punctatus</i> , Röm.
<i>Pleurotomaria neocomiensis</i> , D'Orb.	„ spec. ?
„ spec. ?	<i>Avicula macroptera</i> , Röm.
<i>Trochus</i> „	<i>Lima tombeckiana</i> , D'Orb.
<i>Turbo</i> „	„ spec. ?
<i>Neritopsis</i> „	<i>Trigonia ingens</i> , Lyc.
<i>Emarginula</i> „	<i>Astarte robusta</i> , Lyc.
<i>Pileopsis neocomiensis</i> , Gardn.	<i>Modiola</i> spec. ?
<i>Waldheimia tamarindus</i> , Sow., var.	<i>Cucullæa</i> „
„ <i>tilbyensis</i> , Dav.	<i>Tellina</i> „
„ <i>Walkeri</i> , Dav.	<i>Astarte</i> „
„ <i>faba</i> , D'Orb., non Sow.	<i>Mactra</i> (?) „
„ <i>hippopus</i> , Röm., var.	<i>Sphæra</i> „
„ <i>tilbyensis</i> .	<i>Cyprina</i> „
<i>Terebratula sella</i> , Sow.	<i>Myacites</i> „
„ <i>depressa</i> , var. <i>cyrta</i> .	<i>Pholadomya</i> „
„ „ Lam.	<i>Sowerbya</i> „
„ <i>prælonga</i> , Sow.	<i>Serpula lophoides</i> , Goldf.
<i>Rhynchonella multiformis</i> , Röm.	„ <i>gordialis</i> , Schl.
„ <i>Walkeri</i> , Dav.	<i>Nucleolites</i> spec. ?
„ <i>lineolata</i> , Ph. ?	
„ <i>speetonensis</i> , Dav.	

* Quart. Journ. Geol. Soc., vol. xxxviii., p. 241.

Trigonia nodosa, Sow., *Serpula plexus*, Sow., and *Cucullæa Gabrielis*, Leym., have also been found in the course of the Survey.

The following list is taken from Professor Judd's paper in the *Quart. Journ. Geol. Soc.*, vol. xxiii., p. 246.

List of Fossils from the Tealby Series [Tealby Limestone and Clay, and Claxby Ironstone]:—

Wood (rather abundant).	<i>Pecten</i> (several other species).
<i>Spongia paradoxa</i> , Woodw., and allied forms.	<i>Lima</i> (large species).
<i>Scyphia clavellata</i> , Röm.	<i>Astarte substriata</i> , Leym.
Spines of <i>Cidaris</i> .	<i>Lucina crassa</i> , Sow.
<i>Serpula filiformis</i> , Sow.	<i>Pleuromya</i> , sp.
„ <i>antiquata</i> , Sow.	<i>Panopæa plicata</i> , Sow., sp.
„ sp.	<i>Thetis Sowerbii</i> , Röm.
<i>Vermicularia Sowerbii</i> , Mant. (rare).	<i>Trigonia alæformis</i> , Park.
<i>Terebratula faba</i> , D'Orb., not Sow.	Numerous casts of large <i>Trigonia</i> and other bivalves.
„ <i>hippopus</i> , Röm.	<i>Pleurotomaria</i> , sp.
„ <i>depressa</i> , Lam. (many varieties).	<i>Solarium ornatum</i> , Sow. ?
„ <i>biplicata</i> , var. <i>obtusa</i> , Sow.	<i>Ammonites clypeiformis</i> , D'Orb.
„ <i>sella</i> , Sow.	„ <i>plicomphalus</i> , Sow.
<i>Rhynchonella parvirostris</i> , Sow., sp.	(Several other species of <i>Ammonites</i> , probably new).
„ <i>Gibbsiana</i> , Sow., sp.	<i>Ancyloceras Duvalii</i> , Leveille, sp.
<i>Ostrea frons</i> , Park.	„ <i>puzosianus</i> , D'Orb., sp.
„ sp.	<i>Crioceras</i> ? <i>Bowerbankii</i> , Sow.
<i>Exogyra sinuata</i> , Sow.	<i>Belemnites lateralis</i> , Phil.
<i>Anomia</i> , sp.	„ <i>jaculum</i> , Phil.
<i>Perna ricordeana</i> ? D'Orb.	„ <i>semicanaliculatus</i> , Blain.
<i>Pecten cinctus</i> , Sow.	„ <i>minimus</i> ? Mill.
„ <i>orbicularis</i> , Sow.	Vertebræ and teeth of <i>Ichthyosaurus</i> .
„ <i>elongatus</i> , Lam.	Vertebræ of <i>Plesiosaurus</i> .

The foregoing list may be supplemented by the following genera and species, observed by Mr. H. Keeping in the Tealby Clay and Limestone* :—

<i>Ammonites Carteroni</i> , d'Orb., var.	<i>Trigonia robinaldina</i> , d'Orb.
<i>Crioceras asterianum</i> , d'Orb., var.	<i>T. Keepingi</i> , Lyc.
<i>Littorina</i> .	<i>Cyprina angulata</i> , Sow.
<i>Rostellaria</i> .	<i>Pholadomya rauliniana</i> , d'Orb.
<i>Scalaria</i> .	<i>Pholadomya</i> , sp.
<i>Turritella</i> .	<i>Pleuromya Voltzii</i> , Ag.
<i>Actæon</i> .	<i>Sowerbya</i> .
<i>Avicula</i> or <i>Inoceramus</i> .	<i>Arca</i> .
<i>Avicula pectinata</i> , d'Orb.	<i>Tellina</i> .
<i>Perna Mulleti</i> , Desh.	<i>Nucula</i> .
<i>P. ricordeana</i> , d'Orb.	<i>Myacites</i> .
<i>Lima longa</i> , Röm.	<i>Holaster</i> .
<i>L. abrupta</i> , d'Orb.	<i>Meyeria magna</i> .
<i>L. dupiniana</i> , d'Orb.	<i>Hoploparia</i> .
<i>L. undata</i> , Desh.	<i>Siphonia</i> .

* *Quart. Journ. Geol. Soc.*, vol. xxxviii., p. 241, and MSS.

and by the following species recorded from the Tealby Beds by Mr. W. Keeping* :—

<i>Ammonites Kænigi</i> , Sow.	<i>Cucullæa donningtonensis</i> , Kpng.
<i>A. mutabilis</i> , Sow.	<i>C. errans</i> , Kpng.
<i>A. multiplicatus</i> , Roem.?	<i>Cardium subhillanum</i> , Leym.
<i>Chemnitzia</i> .	<i>Pecten orbicularis</i> , Sow., var. <i>magnus</i> , Keep.
<i>Phasianella</i> .	× <i>Belemnites pistilliformis</i> , Blainv.
<i>Trochus</i> .	× <i>B. subquadratus</i> , Roem.
<i>Crepidula</i> .	× <i>Ostrea Couloni</i> , d'Orb.
<i>Cytheræa</i> .	× <i>O. macroptera</i> .
<i>Lima tombeckiana</i> , d'Orb.	× <i>Avicula cornueliana</i> , d'Orb.
<i>Trigonia</i> (dædaloid form).	× <i>Terebratula tornasensis</i> , d'Orb.
<i>T. tealbyensis</i> , Lycett.	× <i>T. depressa</i> , Lam.
<i>T. ingens</i> , Lycett.	× <i>Waldheimia Juddii</i> , Walker.
<i>Pileopsis</i> and <i>Natica</i> .	

while in the tables (*op. cit.*, pp. 158-164) there are further additions to the Tealby fauna, as follows :—

Cerithium marollinum, d'Orb.
Ostrea frons (Park.) var. *carinata*, Sow.
Serpula antiquata, Sow.
Vermicularia Phillipsii, Römer.

To the above lists additions may be made from the following, all of which have been observed in the Donnington clay-pit in the Tealby Clay :—

Serpula gordialis, Schloth.
Meyeria? and impressions of crustacea.
Exogyra sinuata, Sow.
Perna Mulleti, Desh.
Trochus pulcherrimus, Phil.
Belemnites lateralis, Phil.
 „ *semicanaliculatus?* Blain.
 „ sp.
Ammonites speetonensis, var. *concinus*, Phil.
 „ var. *venustus*, Phil.
Crioceras Duvalii, Lév.

* The Fossils, &c. of Upware and Brickhill, p. 64. The specimens marked thus × are quoted by Mr. W. Keeping, as being common to the Upware and Tealby series.

CHAPTER XI.*

LOWER CRETACEOUS ROCKS—*continued*, AND
UPPER CRETACEOUS ROCKS.*The Carstone.*

The Carstone ranges in thickness from about 36 feet in the south near Cawkwell, to about 14 feet in the north near Claxby. It is a coarse grit, with the intermixture of a sufficient proportion of ferruginous clay to prevent it from becoming a running sand, like the soft parts of the Spilsby Sandstone. The grit particles consist chiefly of quartz, Lydian stone, and hornstone, but a great number of small pebbles of a pale yellow phosphate of lime and of flakes or occasionally spherical grains of iron oxide also occur. There are also bands of larger pebbles, nearly all of which are rolled phosphates, with rarely a fragment of fossil wood. The rock is traversed by veins of iron oxide, and is sometimes cemented into a fairly hard stone by this material. As a rule, the Carstone is more clayey in the upper part, while the largest phosphates are found in a band at the base (p. 112); but there are also pebbly bands in the middle of the rock, as at Donnington. Near its top there run for many miles two or three lines of concretions, formed in place, and consisting of spherical or cylindrical masses of Carstone, cemented by a cement of a ferruginous phosphate of lime. These concretions are found at a scarcely varying distance below the Red Chalk, and serve to show that the bedding of the Carstone and Red Chalk is parallel, and that the passage of the one into the other is real and not merely apparent.† The nature of this passage is shown in the detailed sections given hereafter.

No indigenous fossils have yet been found in the Carstone, but a few specimens have been obtained from the derived pebbles of phosphate of lime; they include *Ammonites speetonensis* (?), *A. plicomphalus* (?), *Lucina* spec.? and others, and a gasteropod. The fossils were obtained by breaking open the large pebbles in the coprolite bed near Otby; a few very much rolled specimens of lamellibranchs were picked up near Donnington also. Mr. H. Keeping states that he has obtained specimens of the following in the Carstone at Claxby, about 5 feet below the base of the Red Chalk:—*Ammonites Deshayssii* (Leym.), *A. bplex* (Sow.), *Requienia*? *Astarte*, *Corbula*, *Modiola*, *Myacites*, *Pholadomya*, *Cyprina*, *Teredo*. The fossils, so far as they go, indicate that

* Written, except where otherwise noted, by Mr. A. Strahan.

† Professor Judd refers to the section at Langton-by-Spilsby as a proof of unconformity, the dip of the Red Chalk being 3° E., while that of the Carstone is apparently 15° E. (*Quart. Journ. Geol. Soc.*, vol. xxiii., p. 243.) The apparent dip of the Carstone here is, however, probably due to current-bedding.

the pebbles were derived principally from the Tealby Beds, a conclusion that is quite borne out by the nature of the material of which they are composed. This consists of an impure phosphate of lime, yellow in colour, and fine-grained, and containing 23·57 per cent. of phosphoric acid, and 32·78 per cent. of calcic oxide, with iron and carbonic acid, the portion soluble in acid being 77 per cent.* In some of the pebbles may be seen imbedded lumps of a darker material, also a phosphate, with small quartz grains. Many of them also contain oolitic grains of iron oxide, similar to those which occur in the Tealby Clay, and are imbedded in the nodules which have been formed in this clay. These pebbles in fact, while quite unlike the nodules which are found in the Spilsby Sandstone, and have been derived from the Kinneridge Clay, have a strong resemblance to the concretions which occur in the Neocomian clays, and they have, without doubt, been derived from beds of this age.

This theory of their origin would imply that a certain amount of erosion of the Tealby Beds took place before the deposition of the Carstone. That this probably was so is further indicated by the fact of the pebbles occasionally occurring as a well-defined conglomerate at the base of the Carstone (as at Otby, p. 112). The whole mass of the Carstone, moreover, is made of such materials (flakes and grains of iron oxide and grains of quartz) as would result from the washing out of the argillaceous constituent from a mass of the Lower Neocomian rocks of Lincolnshire.

The outcrop of the Carstone is marked all through this area (excepting only in the district north of Claxby) by a steep bank capped by the Red Chalk, and resting on a gentler slope of the Upper Ironstone (*see* Figure 4, p. 90). The junction with the Ironstone is almost everywhere concealed by downwash from the friable Carstone, but the junction with the Red Chalk is repeatedly exposed. For this reason, and as the one seems to pass up into the other, the description of the principal sections of the Carstone will be taken with that of the Red Chalk.

The Red Chalk.

This name is restricted to the deeply coloured band which lies next above the Carstone, and forms the base of Chalk; the paler red bands which occur at a higher horizon being distinguished as the Louth pink chalk. From its prominent position at the brow of the escarpment, and from its conspicuous colour, the bed may be traced with ease along almost the whole of its very sinuous outcrop, excepting only in the break in the escarpment made by the valley of the Bain, where it is concealed by Drift.

The thickness of the Red Chalk varies from about 11 feet at the point where it enters this sheet from the east to about 5 feet where it passes from the sheet northwards near Claxby, the rate

* Analysis by Mr. M. Staniland, junior.

of attenuation corresponding pretty closely with that which has been observed in the underlying Neocomian rocks.

The colour is invariably deepest in the lowest bands of the Red Chalk, and fades away in the uppermost bed to a pale pink or yellow. It is due to the presence of iron in the form of the red anhydrous per-oxide, a very small quantity of which is sufficient to impart a deep colour. The following analysis by Mr. M. Staniland, junior, shows the amount present in a typical specimen :—

Analysis of Red Chalk from Stenigote, 4 feet from the top.

Insoluble	-	-	-	-	6.05
Silica	-	-	4.49		
Peroxide of Iron	-	1.56			
Moisture	-	-	-	-	1.08
Lime	-	-	-	-	49.36
Carbonic Acid	-	-	-	-	41.20
Peroxide of Iron	-	-	-	-	1.96
Magnesia	-	-	-	-	1.10
Phosphoric Acid	-	-	-	-	trace
					<hr/> 100.75 <hr/>

Total Fe_2O_3 = 2.66 per cent.

Above the Red Chalk there occurs a hard grey or white gritty chalk with numerous fragments of *Inoceramus*, which Mr. Staniland found to be of the following composition :—

Analysis of the "Inoceramus Bed," Gaumer Hill.

Insoluble	-	-	-	-	3.01
Moisture	-	-	-	-	.56
Lime	-	-	-	-	52.44
Carbonic Acid	-	-	-	-	41.71
Peroxide of Iron	-	-	-	-	1.50
Magnesia	-	-	-	-	.70
					<hr/> 99.92 <hr/>

The detailed sections of the Red Chalk are given subsequently in the order in which they occur; they show that it is divided up into bands by thin partings of red marl, and that its base consists everywhere of a bed of deep red marl from $\frac{1}{2}$ to 1 foot in thickness, and crowded with *Belemnites minimus*. This marl, and the lower beds of Red Chalk, contain abundance of small rounded quartz grains similar to those in the Carstone, and form a lithological passage from the Chalk into the Carstone. The fossils, however, which are abundant in the red beds are entirely absent in the Carstone; the commonest are the *Terebratula biplicata* and *Belemnites minimus*, the former being less, and the latter more abundant towards the base of the deposit. The

supposed mineral structure known as *Spongia paradoxa*,* abounds in the upper part of the red beds.

Description of Sections of the Carstone and Red Chalk.

The outcrop of the Red Chalk owes its great number of sinuosities to the action of springs, which are thrown out by the comparative impermeability of this bed.

The Cawkwell springs, which it was proposed to impound for the use of Horncastle, take their rise from the Red Chalk and the base of the White Chalk. The stream runs between the foot of the Wold and an outstanding ridge of Carstone capped by two small outliers of White Chalk. In the smaller of the two there are two old pits in the White Chalk, but the Red Chalk is shown in *débris* only. On the west side of the larger outlier above the farm there is a pit showing the White Chalk resting on deep-red chalk with *Belemnites*; from the effects of slipping, the beds on the lower side of the pit appear to be dipping steeply down the hill. Such great boulders of chalk as that which is imbedded in the Drift near Timberland (p. 137), probably owe their origin to the breaking off of the edge of such escarpments.

The Carstone is well exposed in a pit at the south end of the larger outlier. At the top there are 2 feet of red marl with *Belemnites* abundant, forming the base of the Red Chalk. This rests upon a yellow ferruginous clayey sand, with scattered grains of quartz as large as peas, and a few derived phosphatic nodules, and pebbles of fossil wood. About 12 feet of the Carstone are exposed.

At the Red Hill Kiln, white chalk, red chalk, and marl are exposed, and the Carstone in the road close by, all except the latter being fossiliferous. The section is as follows:—

	Ft. In.
Compact gritty chalk weathering into flattish nodules, and containing <i>Terebratula semiglobosa</i> and <i>Inoceramus</i> - - - - -	2 0
Very hard rubbly chalk, weathering into very irregular nodules, with yellow-stained surfaces, <i>Ventriculites</i> , <i>Terebratula semiglobosa</i> - - -	1 6
Hard nodular pink chalk, with yellow stains, <i>Avicula gryphaeoides</i> - - - - -	1 6
Yellow parting, hard and sandy - - - - -	0 3
Compact pink chalk, becoming darker below, <i>Ter. semiglobosa</i> , fragments of <i>Inoceramus</i> , <i>Belemnites minimus</i> - - - - -	3 0 +
	8 3

The mineral structure known as *Spongia paradoxa* occurs throughout.

At the back of the farm buildings south of Stenigote there is a fine exposure of the Carstone. It consists generally of a clayey ferruginous sand, sufficiently coherent to stand in a steep bank, but soft enough to admit of a hammer being plunged into it. At the top is seen some red chalk *débris* and red marl, probably not far out of place. In the upper part of the Carstone thin flakes and grains of iron oxide are very abundant, and there are a few scattered phosphatic nodules containing the oolitic grains of iron oxide so common in the Neocomian clays. Grains of clear quartz, rounded or sub-angular, are also abundant, and by their prevalence along certain bands, indicate stratification. In the lower part the Carstone is traversed by irregular veins of iron oxide, and is more rocky. The base appears to be at about the level of the farm buildings, where the Neocomian clays succeed. The thickness of Carstone exposed is 35 feet.

Further to the south, grey clay with *Belemnites* is turned up by the plough immediately at the foot of the Carstone bank, but the junction is nowhere exposed. Through all this neighbourhood the Carstone forms a steep bank

* Prof. T. McK. Hughes (*Quart. Journ. Geol. Soc.*, vol. xl, p. 273, 1884) has given reasons for believing it to be not organic.

unsuitable for cultivation, and devoted to plantations, the belt of wood roughly indicating the outcrop of the subdivision.

Following such a belt round the valley above Stenigote, we are brought to the west end of the Withcall Tunnel on the Louth and Lincoln Railway, where is afforded the best section in Lincolnshire of the base of the White Chalk, the Red Chalk, and the greater part of the Carstone.

The Red Chalk crops out above the masonry of the tunnel, about 9 feet above on the north, and about 6 feet on the south side, owing to a slight dip; a small fault throwing the beds down to the east about 2 feet is also visible in the Red Chalk on the south side. The upper part of the cutting is in the White Chalk, the tunnel itself starting in the Carstone, but rising towards the east in the direction in which the beds are dipping, and passing gradually up into the Red and White Chalk; the interior, however, is bricked up. A descending section at the west end of the tunnel shows the following details; the observations of the White Chalk were made by Mr. Jukes-Browne:—

Withcall Tunnel; west end.

		FT.	IN.
Lower Chalk (top not seen).	Chalk weathering into small plaquettes or lenticular fragments	12	0
	Layer of yellowish grey shale.		
	Hard chalk, whiter and less gritty than that below	1	6
	Layer of grey shaly marl.		
	Hard grey gritty chalk with shaly layers full of <i>Inoceramus</i> (the " <i>Inoceramus Bed</i> "); <i>Holaster subglobosus</i> also occurs	5	0
Red Chalk, 11 ft. 2 in.	Hard nodular grey chalk with yellow stains, weathering into rough lumps; <i>Terebra- tula biplicata</i>	1	6
	Pale pink and yellow chalk, becoming pale red below	5	0
	Shaly parting	0	4
	Dark red chalk (<i>Nautilus simplex</i>)	2	10
	Shaly parting	0	6
Carstone, 36 ft.	Dark red nodular chalk with <i>Terebratula biplicata</i> and <i>Belemnites</i> abundant, and with grains of quartz and flakes of iron oxide	1	6
	Red marl with <i>Belemnites</i> abundant, and grains of quartz and iron oxide	1	0
	Yellow very gritty clay, full of quartz grains with yellow ferruginous phosphatic con- cretions (formed in place)	0	6
	Grey sand with yellow and reddish-brown streaks and patches, and ferruginous phosphatic concretions (formed in place)	5	6
	Brown and grey mottled sand with occa- sional lumps of grey clay	8	0
	Pebbly band, containing numerous flakes of iron oxide, small quartz pebbles, and well-rolled phosphatic nodules (derived) containing oolitic grains of iron oxide	4	0
	Brown and grey sand with clay galls, as above	3	0
	Brown sand with a few grey patches	9	0
	Beds not seen, estimated at	6	0
		67	2

In the next cutting towards Donnington the Red Chalk has slipped over the Carstone, making the junction appear very irregular; but in the third cutting there is a clear section as below:—

		Ft.	In.
Red Marl (base of the Red Chalk).			
Carstone, 36 ft.	Grey sand and yellowish gritty clay very irregularly mixed, streaked and mottled with red -	1	0
	Loose grey sand with brown mottles, and containing scattered quartz pebbles as large as peas, and three lines of ferruginous phosphatic concretions (formed in place) about -	8	0
	Pebbly bed (as in preceding section) -	4	0
	Loose brown sand -	4	0
	Coherent brown sandstone, traversed by veins of iron oxide -	8	0
	Beds not seen, about -	11	0
		<hr/> 36	<hr/> 0

The concretions, referred to in the above sections as formed in place, are masses of Carstone cemented into a spheroidal or a hollow cylindrical form by a ferruginous and calcareous phosphate of lime. They are very constantly found at this horizon in the Carstone along the greater part of the Wold escarpment. In the last-named section they occur in lines at $\frac{1}{2}$ foot, at $1\frac{1}{2}$ foot, and at 4 feet distance from the top of the Carstone, those in the highest band being cylindrical, the others irregular, in form. In the tunnel section the same three lines may be identified.

The phosphatic nodules, which are noted as being derived, are well-rounded pebbles about $\frac{1}{2}$ to 1 inch long, yellow outside and dark inside, many of them containing the Neocomian oolitic iron grains. Very rarely the half-obliterated form of a fossil may be detected, showing that some at least are the water-worn casts of fossils, as is so commonly the case in derived phosphatic nodules. There is good reason to believe that in this case they have been derived from the Middle Neocomian Clays, as has been previously described.

The Red Chalk is next seen near two quarries on Nob Hill, one on the south and the other on the north side of Pan Holes Lane, in both cases with a gentle dip to the east. In the latter the base of the Red Chalk is reached by the side of the kiln, and the following section was observed by Mr. Jukes-Browne:—

		Ft.	In.
Lower Chalk	Greyish-white chalk in thin beds -	12	0
	Seam of yellowish-grey marl.		
	Hard grey chalk full of <i>Inoceramus</i> , nodular above, more massive below	4	6
	Yellowish and grey nodular chalk -	1	6
Red Chalk, 9 ft. 6 in.	Yellow and pink chalk -	1	6
	Darker pink chalk passing down into dark red chalk -	8	0
Carstone	Red sand, said to have been touched below,		

A pit by the side of the road from Donnington Mill to Welsdale Bottom shows:—

	Ft.	In.
White chalk becoming pink in the lower 6 inches (<i>Terebratula semiglobosa</i>) - - -	2	0
Pink chalk - - -	1	3
Yellow parting - - -	0	0½
Red chalk with <i>Belemnites</i> and <i>Spongia paradoxica</i> -	5	0+
	<u>8</u>	<u>0½</u>

From this point the Red Chalk with the underlying Carstone may be easily traced for about $\frac{1}{2}$ mile, but then for the first time is overspread by Boulder Clay. Emerging within a short distance, it can be followed without difficulty round by Welsdale Bottom and up the valley leading north from Grimblethorpe. At this point, however, it is lost for a considerable distance under the great mass of Drift which occupies this part of the Bain Valley. It is again found at the surface along the upper part of the Bain near Wykeham, and in a small inlier at Ludford, the head waters of the Bain being principally derived from the springs from this bed.

By Girsby House the Red Chalk and Carstone are concealed, but re-appear about Ludford Tongue as before, in consequence of the Drift having been cut through in the upper part of the valley.

A kiln at the "Heneage Arms" shows some small faults in the white and Red Chalk, not an unusual circumstance in this part of Lincolnshire. On the north side of the kiln the white Chalk dips W. 30° N. at 15° to 20° . On the west side the Red Chalk is reached with a small down-throw to the east, running N. 11° W. The Red Chalk would rise to the surface about the middle of the pit; there must therefore be other faults throwing the beds down to the east. On the south side of the road are some old pits, in one of which white chalk is seen dipping to the N.W. at 18° ; and a short distance further south by the side of the High Street there are pits showing the position of the Red Chalk and Carstone, with a dip to the N.N.W. of 12° . Close by the road here on the west side there is evidence again of a small fault running a little west of north throwing the Red Chalk down on the east against the Carstone. From the form of the ground there is little doubt that these displacements are true faults and not due to slipping. Their prevalent direction is about N. 12° — 15° W.

From the "Heneage Arms" the Red Chalk and Carstone may be traced with scarcely an interruption beyond the margin of this sheet, the latter nearly everywhere forming a pronounced bank with springs issuing from the foot. They begin to show here the thinning out, in consequence of which the Red Chalk partly, and the Carstone wholly, disappear further north (Sheet 86). Some clear sections occur in the valley running north from Otby about one mile east of Normanby-on-the-Wolds. The following section was measured from exposures of the Red Chalk and Carstone and upper part of the Middle Neocomian Clay, west of the barn marked on the Ordnance Map; the details of the lower part of the section were observed near an old level driven for iron-ore, about one-third of a mile north-north-east of Otby.

The Otby Valley, near Normanby-on-the-Wolds.

	Ft.	In.
White chalk, shaly with irregular partings (fragments of <i>Inoceramus</i> abundant) -	1	10
Red Chalk, { Yellow chalk becoming pale red below -	1	0
6 ft. { Red chalk -	4	0
{ Lumps of red chalk imbedded in red marl with grit - - -	1	0

		Ft.	In.
Carstone, 20 ft. 6 in.	Very gritty clay, yellow and red above, with numerous small quartz and hornstone pebbles, and two lines of concretions formed in place	2	0
	Brown sand with small scattered pebbles, cemented in part into a brown friable sandstone by iron oxide	18	0
	Band of large rolled phosphatic nodules, embedded partly in brown sandstone, partly in yellow ferruginous clay.		
	Strong springs	0	6
	Tealby Beds; Upper Ironstone (for details see p. 100)	25	3
		53	7

The thickness of the Carstone in the above section is 20 feet 6 inches as compared with 36 feet at the Withcall Tunnel. It will be observed, however, that two similar lines of concretions formed in place occur just below the base of the Red Chalk, the one at $\frac{1}{2}$ foot, the other at $1\frac{1}{2}$ feet below. The brown sand and friable sandstone is precisely similar to that of the tunnel section, except in the absence of the pebbly band of rolled phosphates seen in the middle of it at the tunnel. This, however, is an unimportant variation. The principal point of interest in this section is the exposure of the band of large rolled phosphatic nodules at the base of the Carstone. These nodules vary from $\frac{1}{2}$ inch to 3 or 4 inches in diameter, and are very irregular in shape, though all are considerably rounded and water-worn. Some are clearly casts of fossils, and many of the large ones, when broken, disclose fragments of *Ammonites*. The following specimens were obtained:—

Ammonites speetonensis (?) four specimens.

Do. *plicomphalus* (?) one specimen.

Lucina (?) and others, and a gasteropod.

About Normanby the Red Chalk and Carstone may be easily traced, but are not again well exposed within the margin of this sheet.

The Stainton Inlier.

There are two inliers of Red Chalk and Carstone in the Chalk area in this sheet, the small one at Ludford previously referred to, and the far larger exposure extending from Stainton-le-Hole to Thorpe-le-Mire. The exposure of these beds is due to the action of a vast number of springs which continually eat their way back up the dip-slope toward the elevated Wold escarpment to the west; in some cases (Sheet 84) the white Chalk has been cut through, with the exception of a narrow neck scarcely broader than a road, by such action. So labyrinthine are the boundaries of the Stainton Inlier that the outcrop of the Red Chalk, enclosing an area of less than 3 square miles, has a length of about 25 miles. The springs burst out partly from the Red Chalk and partly from the base of the Carstone, which forms a steep bank along the west side of the inlier. The bottoms of the valleys are occu-

pied by the Tealby limestone, overlaid along the foot of the Carstone features by the clays described in the section at Otby (p. 100).

The Carstone is exposed near Orford to a depth of about 8 feet, but neither the top nor the base is seen. It consists of brown sand traversed by veins of iron oxide, and with a pebble-bed about 1 foot thick. The larger pebbles are about 1 inch long, and consist of phosphatic nodules, but quartzites and shale or slaty rocks also occur.

East of Thorpe-le-Mire the Red Chalk is seen resting on about 10 feet of Carstone with the usual concretions formed in place, and with derived pebbles. The Carstone makes a steep bank, at the foot of which is a line of quaking hogs, marking the junction with the Neocomian clays. The springs, it may be observed, burst out on the westerly side of the ravines, as a natural result of the general easterly dip of the beds. South of, and at Thorpe-le-Mire, strong springs issue from the Red Chalk on the west side of the valley. After rain the water issues in small cascades from tortuous holes 2 to 4 inches in diameter in the chalk. It is probable that the sinuosities in the sides of the valleys are due to such springs having broken out from time to time at different points. The settling of the sides of the ravines would tend to open fresh cracks from time to time and change the underground channels.

A pit on the north-east side of Thorpe-le-Mire shows :—

	Ft.	In.
Grey knotty chalk - - - - -	-	1 0
Shaly parting - - - - -	-	0 1
Grey knotty chalk - - - - -	-	5 6
Shaly parting - - - - -	-	0 1
Grey knotty chalk - - - - -	-	1 0
Shaly parting - - - - -	-	0 1
Very coarse irregular chalk - - - - -	-	4 0
Beds not seen, about - - - - -	-	6 0
Red chalk - - - - -	-	1 0+
		<hr/> 18 9 <hr/>

and in the ravine running south-west from a little north of Thorpe-le-Mire there is exposed :—

	Ft.	In.
Grey chalk with <i>Inoceramus</i> and fragments of <i>Echinoderms</i> - - - - -	-	3 0
Pale-yellow nodular chalk with pale-red spots - - - - -	-	1 2
Red and yellow mottled nodular chalk with <i>Spongia paradoxica</i> abundant - - - - -	-	1 0
Deep-red nodular chalk, not very fossiliferous - - - - -	-	3 0+
		<hr/> 8 2 <hr/>

The yellow colour occasionally follows the jointing through the red beds, indicating that a partial bleaching has taken place, probably by the reducing action of soil water on the red peroxide of iron which forms the colouring matter. The mineral structures, known as *Spongia paradoxica*, are often yellow in the red beds, or partly red and partly yellow where they intersect one of those joints along which the bleaching agents have been at work.

In the next ravine about $\frac{3}{4}$ mile north-west of Thorpe there are two pits in the Tealby Limestone, showing the same beds as at the kiln near the "Heneage Arms," with *Ostræa frons*, *Pecten cinctus*, and *P. orbicularis*. The limestone is hard and blue, and in bands separated by beds of soft brown earthy sand. The dip is to the south-east at 55° , probably through some local slipping; there is no evidence of any fault or roll in the Carstone or Red Chalk.

In a road cutting on the north side of Kirmond-le-Mire, the beds are seen as below :—

		Ft.	In.
	Grey nodular chalk with much shale and flaky beds (<i>Inoceramus</i> and <i>Terebratula</i> abundant) - - -	1	3
	White nodular chalk, passing down - - -	0	9
Red Chalk, 8 ft. 7 ins.	Pale pink and yellow chalk with <i>Spongia paradoxa</i> abundant and a small <i>Terebratula</i> , becoming redder below - - -	2	1
	Red chalk, pale for top three inches, dark below, <i>Terebratula semiglobosa</i> , <i>Belemnites minimus</i> and <i>Inoceramus</i> abundant - - -	4	6
	Red shale and nodular chalk - - -	2	0
	Yellow ferruginous sandy clay laminated, and with red streaks - - -	0	10
Carstone, 3 ft. 10 ins. +	Line of concretions. - - -	-	-
	Sand with pebbles - - -	1	0
	Line of concretions. - - -	-	-
	Sand with pebbles - - -	2	0+
		<hr/>	<hr/>
		14	5

A chalk-pit on the road to Tealby shows bands of nodular flaky chalk alternating with greenish-grey shales in beds about one foot thick. The nodular and flaky chalk is of a very pale pink in some parts. It may be on the horizon of one the pink bands seen near Louth.

Near Stainton-le-Hole, grey and pale-blue clays are seen occasionally just below the base of the Carstone, but there are no sections of the junction in consequence of the springs. At Stainton Vale House there is a pit in the Carstone showing:—

	Ft.	In.
Hard dark-brown sandstone, bedded and jointed, and with a few scattered pebbles smaller than peas - - -	3	0
Band of rolled phosphatic nodules about as large as broad beans - - -	0	8
Brown sandstone with small scattered pebbles - - -	3	0+
		<hr/>
		6 8

Half a mile south of Stainton there is a good spring issuing from the Carstone. The rock is hard, but friable and brown, and contains large rolled phosphatic septaria and nodules, some of which are obscure casts of fossils. The base is not seen, but fragments of a conglomeratic band are seen in the bed of the stream, probably portions of a basement bed similar to that seen near Othby about $2\frac{1}{2}$ miles to the west. The total thickness of Carstone appears to be little less than 40 feet. This appears to be an unusual amount as compared with the $20\frac{1}{2}$ feet seen at Othby, even supposing a general easterly thickening to take place, as noted by Professor Judd.

The Tealby Limestone is found again in lumps lying about in the ravines west of Stainton; but the sections are much obscured by a wide-spread deposit of small chalk fragments in loam. This is particularly the case along the northern part of the inlier, where the Red Chalk is almost everywhere concealed. There is no reason to attribute this deposit to glacial action; it has probably been distributed by floods recurring at intervals through a great number of years. No Glacial Deposits occur in these valleys in this part of the Wold; they keep, on the contrary, to some of the highest ground, to the east of Binbrook. The present form of the inlier appears to have been produced in post-glacial times by the action of springs, as described above. The extension of some of the ramifications towards the west is now a matter of almost yearly observation.

The Lower Chalk.

Mr. Jukes-Browne contributes the following account of what by contrast with the underlying rock may be termed the "white"

chalk :—For a general description of the Lincolnshire Chalk and its subdivisions the reader is referred to the explanation of the neighbouring Sheet 84. Here it will be sufficient to give a tabular view of the subdivisions of the Lower Chalk as developed near Louth, the same beds being recognisable also in Sheet 83.

	Fr.
G. Soft shaly marl, grey, but often variegated with red and purple	2
F. Hard white chalk, in thick beds, sometimes stained yellowish-pink in the upper part	22
E. Hard greyish-white chalk with marly bands, sometimes pink at the lower part	14
D. Two beds of nodular grey chalk, enclosing a band of compact grey chalk*	6½
C. Rough greyish-white chalk, in thin beds weathering into nodular lumps	28
B. Hard grey gritty chalk, in massive beds ("Inoceramus beds")	5
A. Hard lumpy chalk, yellowish-white or pink	1½
	<hr/> 79

The lowermost beds of the above series (A., B., C.) are exposed in some of the sections already mentioned, namely, at Red Hill (p. 108), at Withcall Tunnel (p. 109), at Nob Hill (p. 110), near the "Heneage Arms" (p. 111), at Thorpe-le-Mire and Kirmond-le-Mire (pp. 113, 114). An analysis of the Inoceramus bed is given on p. 107.

The central beds (D. and E.) of the Louth section have been seen at the following localities:—

The cutting at the eastern end of the tunnel between Withcall and Donnington is through Lower Chalk containing a band of pink chalk, broken by numerous small faults, each with an upthrow on the western side and giving the beds a tilt to the westward. The section in the middle of the cutting, taken close beside a fault with a throw of 9 or 10 feet, is as follows:—

	Fr.
Soil and greyish chalk	2
Pink chalk, many lumps white in the centre	5
Hard grey chalk in well-marked beds	6
Talus of fragments	12
	<hr/> 25

Further to the east, and just beyond the margin of this Sheet, the continued faulting brings up the base of the Chalk with the underlying Carstone, which has been dug in a small sand-hole near Withcall Farm (see Explanation of Sheet 84). As these faults produce a westerly dip, and as the dip at the west end of the tunnel is normal, viz., a slight inclination to the east, the ridge through which the tunnel passes must be a shallow synclinal trough.

A pit on the south-east side of Pan Holes Lane (E.N.E. of Donnington Station) shows the following section in the same beds:—

	Fr.	In.
Thin-bedded chalk with marly layers and a band of pink chalk	15	0
Hard nodular grey chalk	2	6
Thin seam of yellowish grey marl.		
Course of hard massive dark-grey chalk	1	6
Looser nodular grey chalk	2	0
Greyish-white chalk in thin beds and weathering into flattish nodular fragments	6	0
	<hr/> 27	<hr/> 0

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* Mr. W. Hill, F.G.S., has recently examined the Lower Chalk of Lincolnshire, and informs me that he believes that these beds include a representative of the Totternhoe stone.

The following sections are probably all of them in the middle and upper portions of the Lower Chalk :—

In pits near Ludford Windmill there occur :—

	Ft.
Bands of hard white chalk 3 to 12 inches thick, alternating with thin grey shaly bands	8
Hard grey knotty chalk without flints	5 +
	<hr/> 13

North-east of the Windmill the bands of chalk break into blocks suitable in size and hardness for building.

One mile north-east of Thorpe-le-Mire a pit shows :—

	Ft.
Grey flaky chalk with thin grey shaly partings; <i>Inoceramus</i> abundant, and fragments of <i>Rhynchonella</i>	10 +
And another pit, $\frac{1}{4}$ mile N.E. of Stainton Church, shows beds of well-jointed chalk, alternating with beds of shaly chalk not jointed.	

In a pit on the west side of Bully Hill, between Tealby and Kirmond, there is seen hard flaky thin-bedded chalk without any shale, but a pit on the High Street one mile further south and at a higher horizon exposes :—

	Ft.
Flaky chalk with thin shaly partings	8
Rocky chalk in beds of 8 to 12 inches	6 +
	<hr/> 14

Similar flaky chalk is seen in pit on the High Street north of Bully Hill.

Further to the north, at the cross road leading to Walesby, there occurs :—

	Ft.
Flaky chalk (as at Bully Hill) breaking into small lumps through the intersection of vertical jointing with thin bedding; more shaly below	10
Hard rocky chalk not jointed, in beds of 1 to $1\frac{1}{2}$ feet with shale partings of 3 to 6 inches	6 +
	<hr/> 16

At the east end of this pit is a small fault running about N.N.W. and throwing the beds 8 or 9 feet down to the east. Half a mile to the north-north-west a pit above Othy shows :—

	Ft.
Flaky chalk (as at Bully Hill)	3
Do. with shale partings	2
Hard rocky chalk in beds of 1 to $1\frac{1}{2}$ feet with shale partings	8 +
	<hr/> 13

A pit at Risby Hall shows a similar sequence.

This series of sections seems to show that the upper part of the Lower Chalk in this neighbourhood is of a thin-bedded shaly character, the beds below being more solid and less split up by shale partings. The lowest beds of the white chalk, however, are more shaly again, as shown in the sections at Thorpe le-Mire, given on p. 113, and at Nob Hill and Withcall Tunnel (p. 109), but are not so consistently thin-bedded as the series described above.

The bands of pink chalk exposed at the east end of Withcall Tunnel, and by the road leading from Kirmond-le-Mire to Tealby, have already been referred to. A similar bed is exposed near

Binbrook on the north flank of the ridge running south-south-east from the village. These beds of pink chalk are well seen in the neighbourhood of Louth, on which account they have been termed the Louth red chalk,* for an account of which the reader is referred to the Explanation of Sheet 84.

The highest part of the Lower Chalk, including the band of shaly marl, which is believed by Mr. Jukes Browne to represent the Belemnite marls of the Midland counties, were only seen at one locality, viz., in a pit by the barn one mile east-south-east of Gayton-le-Wold, where he noted the following details:—

	Ft.	In.
Chalky soil - - - - -	-	0 6
Broken marly chalk - - - - -	-	2 0
Buff marl with chocolate-red marl below and a layer of hard yellowish chalk nodules at the base - - -	-	1 6
Hard yellowish white chalk with thin seams of yellow and red marl . - - - -	-	5 0
		<hr/> 9 0

The beds dip at about 4° to the W.N.W.

The Middle Chalk.

The Chalk which overlies the band of variegated shaly marl has been correlated on palæontological grounds with the Middle Chalk of Cambridgeshire. It is divisible into two portions, one without and one with flints, these two parts being much more sharply divided from one another than is the case in the Midland counties. The succession of beds composing the Middle Chalk in Sheets 83 and 84 is as follows:—

	Ft.
C. Firm white chalk with lines of flint nodules and continuous layers of flint - - - - -	about 100
B. Firm white chalk with flint nodules - - - - -	about 50
A. Yellowish grey chalk without flints, in massive beds with shaly partings - - - - -	about 14

The lowest beds (A.) contain *Inoceramus mytiloides* and *Rhynchonella Cuvieri* in abundance, and may be regarded as representing the zone of *Rhynch. Cuvieri*. The higher beds (B. and C.) contain few fossils except *Inoceramus Brongniarti*, but probably correspond with the zones of *Terebratulina gracilis* and *Holaster planus*.

At the top of the lower zone there is generally a layer of grey shale, and the basal bed of B. is a thin course of white chalk, which is traversed by a number of close vertical joints so that the bed weathers into a series of rectangular lumps and bears a certain resemblance to a bed of columnar lava.

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The junction of subdivision B. with the flintless chalk is shown in a pit $\frac{1}{2}$ mile north-west of Stainton Vale House. The section is as follows:—

	Ft.	In.
Middle Chalk {	White chalk with two bands of flints; close vertical jointing - - -	6 0
	Shale - - - - -	0 1
	Hard greyish chalk with bands crammed with fragments of <i>Inoceramus</i> and small concretions, well-bedded, no flints; breaking out in square lumps suitable for building; not jointed - - -	9 0
		<hr/> 15 1
		<hr/>

* *Quart. Journ. Geol. Soc.*, vol. xxiii. (1867), p. 237.

The same junction was observed by Mr. Jukes-Browne in a small pit 3 furlongs south-south-east of the farm in Welsdale Bottom, which showed :—

	Ft.	In.
Soil and chalk-rubble	-	2 0
Hard white chalk with lines of flint-nodules	-	6 0
Hard white chalk, jointed so as to break into squarish lumps (columnar band)	-	0 6
Grey shaly chalk	-	0 6
Hard nodular grey chalk	-	2 0
	<hr/>	11 0

On the north side of the Louth Road near Great Tows there is seen :—

	Ft.	In.
White chalk without flints	-	4 0
Grey shale or marl	-	0 2
Hard greyish and white chalk	-	2 0 +
	<hr/>	6 2

The highest beds occur only in the north-east corner of the Map, and some of the flint layers are of a very unusual and peculiar character, consisting of sharp angular lumps or fragments of flint imbedded in a hard chalk, the whole behaving as if it were a homogeneous bed with well-marked upper and lower surfaces. These beds are exposed in several pits near Lambcroft, Binbrook, and Cadeby.

The following notes were taken by Mr. Jukes-Browne in a pit half a mile north-west of Lambcroft :—

	Ft.
Dark-brown sandy soil, full of flints, with pipes and hollows at base	3
White chalk in thin beds with six layers of the imperfect flint above described	14
Greyish-white shaly chalk	1
White chalk in beds about a foot thick, with two courses of solid grey flint	8
	<hr/>
	26

An old pit east of Binbrook House shows similar chalk with bands of white flint. The same series was also observed by Mr. Jukes-Browne in a quarry 5 furlongs W.S.W. of Cadeby House, as below :—

	Ft.	In.
Broken chalk	-	2 0
Large lenticular nodules of grey flint, forming almost a continuous layer, up to	-	0 6
Brittle white chalk	-	4 0
Thin layer of grey marl	-	—
Brittle white chalk	-	2 0
Course of imperfect brown flint and hard chalk closely intermixed, up to	-	0 6
Dull white brittle chalk	-	4 0
Course of large flint nodules	-	—
Soft brittle chalk and talus	-	8 0
	<hr/>	21 0

Similar beds were found by him to be exposed in a smaller pit in the avenue east-north-east of the above, where some of the large lenticular flints attained a length of from 18 to 24 inches. In both pits the mass of the chalk was white and brittle, while the chalk included in the course of imperfect flint is very hard and slightly tinged with buff.

CHAPTER XII.*

GLACIAL DEPOSITS.

INTRODUCTION, PHYSICAL GEOLOGY, &c.

The following subdivisions of the superficial beds are distinguished on the Drift Edition of this Map.

		{ Alluvium.
		{ Peat (partly marine).
Recent and	{	Fen-silt (marine).
Post-Glacial	{	River gravel and Terraces.
	{	Old Blown Sand.
	{	Ancient Gravels.
Glacial	- {	Boulder Clay.
	- {	Sand and Gravel.

The Glacial Deposits occur in the greatest force in the broad tract of low ground which separates the escarpments of the Lower Oolites and the Chalk. Underlain by such soft beds as the Oxford and Kimeridge Clays, this plain must have existed in pre-glacial times in more or less its present form, gaining slowly in breadth as the chalk escarpment retreated through denudation. Northwards it extends as far as the River Humber, but then quickly narrows away, owing to the running together of the two escarpments; southwards it merges into the fen-land, an arm of which extends as far as Lincoln. The existence of the fen-land itself, as such, is primarily due to the intercalation of these soft clays between the Lower Oolite and Cretaceous rocks.

The low tract referred to above is drained by the rivers Witham and Ancholme, flowing south and north respectively. The Witham, rising south of Grantham, flows for the earlier part of its course over the Lias in a northerly direction, and roughly parallel to the Oolite escarpment, as far as Lincoln, where it is joined by the Till, a smaller stream following a corresponding course from the north. Breaking through the escarpment of the Oolites, it then enters the low-lying tract above described, and running in a general south-easterly direction in an artificial channel cut along the margin of the arm of the fen, reaches the sea near Boston. Below Lincoln it is further increased by the number of small becks which gather the drainage of the southern portion of the Drift-covered Oxford and Kimeridge Clay areas. The principal of these becks are the Langworth river from the north, the Bardney Beck from the north-east, and the river Bain, which rising in the Wolds flows through an ancient gap in the Wold escarpment southwards by Horncastle.

The northern boundary of the Witham basin runs from Lambcroft by Great Tows, and Ludford Mill to Sixhills, and from

* Written, except where otherwise noted, by Mr. A. Strahan.

thence by North Wood and about a mile south of Market Rasen by Newton Grange to Spridlington. Passing thence on to the Oolite range, it turns northward to Glentworth, crosses the Boulder Clay plain to Springthorpe, and passes within a mile of the Trent at Gainsborough. From here it runs southwards near Saxelby Station, and thence meanders over a low plain, the water-shed between the Witham and the Trent being so low in this part that the floods of the one have been known to pass into the drainage area of the other.

The breach by which the Witham passes the Oolite escarpment is undoubtedly a feature of great antiquity. The method by which rivers have established courses cutting across bold escarpments has been long understood. It is sufficient to state here that the Lincoln gorge must have been commenced at a time when the Oolites overspread much of the ground to the west of the present position of the escarpment. The overlap of the Oolitic by the Cretaceous rocks, shows that before the deposition of the latter, the Oolites had received a slight tilt from west to east, the effect of which was to expose them to denudation, particularly in the western parts. The Chalk is thus found to pass across the outcrops of the Oolitic rocks, resting on what has been termed "a plane of marine denudation." In the present district the boundary of the Chalk is found at many miles distance from that of the Oolites; the fact, however, that it even now overlaps the whole of these rocks in Yorkshire and in the south of England gives great probability to the view that it must have done so also in Lincolnshire and the Midland Counties. The retreat of the Chalk under the influence of denudation must have exposed a plain having a gentle easterly inclination, down which lines of drainage would be established. Simultaneously with the deepening of these cross lines, longitudinal valleys following the strike of the softer beds would come into existence, leaving the harder rocks standing up as escarpments.

But it is possible that the Lincoln gorge was initiated even before the Chalk was removed from above the Lower Oolites. For the Humber traverses the Oolitic and Chalk escarpments in succession by a cross valley of obviously similar origin; and the Chalk escarpment is again broken through by the estuary of the Wash in a manner that suggests that here also is a very ancient outlet for the drainage of the eastern Midland Counties. Such breaks in the Chalk escarpment would appear on the above theory to have been commenced by rivers running down an old dip-slope of Chalk. However this may be, the above sketch may serve to show what is believed to have been the origin of the apparently anomalous lines of drainage across the bold Oolitic escarpment.

In its lower reaches the Witham valley is for the most part excavated in Glacial Deposits. But from a general consideration of the level of the rock-surface, it appears that the main lines of drainage across the low tract east of the escarpment must have

been much the same in pre-glacial times as now. For example, the surface of the Kimeridge Clay (beneath the Boulder Clay) sinks from the existing watershed towards the fen of the Witham. Similarly, as Mr. Ussher subsequently (p. 136) notes, the surface of the Oxford Clay sinks towards the present valley of the Ancholme.

A portion of the Bain valley also is clearly of pre-glacial age. Rising, as previously stated, in the Wold, it descends thence to the low-lying plain by a broad breach in the Chalk escarpment, in which for a distance of about two miles (between Biscathorpe and the "Heneage Arms") Glacial Deposits completely obscure the well-known features of the Neocomian rocks. Taking advantage of the break in the escarpment, the Drift runs, in what was once a continuous tongue, from the highest part of the Wold down to the Kimeridge Clay plain, clearly proving that the break in the hills had been formed previously to the Glacial Period. It may be noticed that where the outcrop of the Neocomian rocks and Red Chalk is still buried beneath Boulder Clay, as in the case of the small outlier near Biscathorpe, the slope of the escarpment is far more gentle than in those parts where the features have been subjected to and intensified by post-glacial denudation. It is interesting also to compare this part of the Bain valley with that between Biscathorpe and Goulsby, which forms a good example of post-glacial denudation on a large scale. North of Biscathorpe the valley is occupied by Drift, the hills (as about Great Tows and between Gayton and Welton) being principally bare; south of Biscathorpe, the hills bounding the valley (on the west side) are all capped by Drift, the valley itself being in the solid rock. This part of the valley is continuous with that of the Steeping which forms an instance of post-glacial denudation on an unusually extensive scale. (Explanation of Sheet 84.)

The formation of the breach in the Wold escarpment, though no doubt partly contemporaneous with that in the Oolites at Lincoln, has taken place in quite a different way. It may be attributed to the eating back of the Chalk by springs issuing in pre-glacial times, as now, from its base. The process is being carried on now in the smaller valleys which penetrate the Wold near Tealby, and at Otby, near Normanby-on-the-Wold. The springs are so circumstanced that a slight advantage gained by one of them in the process of backward erosion tends to increase the source of supply of that spring to the detriment of those near it. For the greater part of the rainfall that sinks into the Chalk travels eastwards in the direction of the dip, so that the supply of water at any point is to a great extent dependent on the area of Chalk to the westward of that point. Any one spring therefore eating its way eastwards enters an area of more copious supply, and grows in volume at the expense of its neighbours. A chance fissure or undulation in the Chalk has probably given in the cases mentioned above a slight original advantage, which once obtained would, for the reasons stated, be probably increased.

GLACIAL DEPOSITS.

Sand and Gravel.

The best development of this member of the Glacial Deposits is found about South Willingham, Donnington-on-Bain, and Brough-on-Bain. A glance at the map will show that the distribution of these gravels is directly connected with the old breach in the Chalk escarpment which has been described above. They are found in their greatest development in the very breach itself, about Brough and Biscathorpe. Southwards they extend but a short distance beyond South Willingham and Market Stainton; north of Brough they are rapidly overlapped by the Boulder Clay, re-appearing only in small lenticular patches about Kelstern.

These gravels have been largely worked in numerous places for road-metal. Among the boulders flints are by far the most abundant, but fragments of Neocomian rocks (Lower Neocomian Sandstone and Tealby Limestone) are also common, and the small oolitic grains of iron oxide, which occur so abundantly in the Neocomian clays, are found in the sands. The series is well stratified, but lenticular masses or tongues of a brown Boulder Clay, made up largely of the local clays, appear in it in an irregular manner.

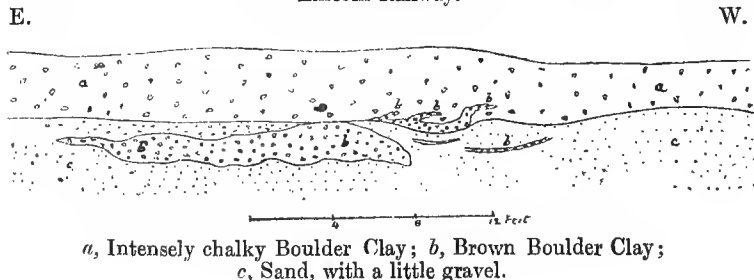
The most southerly exposure of this development of sand and gravel is near Stainton Hall, one mile south-east of Benniworth. On the north-west side of the hall a long gravel-pit shows about 6 feet of loose gravel, interstratified in parts with bands of grey sand composed of small rounded grains of flint. At the west end of the pit the gravel rests on the Lower Neocomian Sandstone; at the extreme east end of the pit there occurs chalky Boulder Clay on about the same level as, and only about 30 yards distant from, the stratified gravel. It is not, therefore, clear here whether the Boulder Clay passes horizontally into the gravel or overlies it, though it appears probable from the mapping that the clay overlies the gravel with an irregular junction. Another small pit, 100 yards nearer the Hall, shows loose unstratified gravel jumbled up with sandy pockets, probably a gravelly patch in the Boulder Clay.

In the road to Benniworth there appears to be much brown or blue Boulder Clay mixed up with the sand and gravel, as in the east end of the Benniworth Tunnel, but 300 yards south-south-east of Benniworth Grange some small openings show very fine pale-buff sand, with bands of loam, belonging to this series. This and the Stainton Hall pit appear to be in the thin end of the wedge of sand and gravel that runs up to Willingham and Brough.

The best sections, illustrating the relations of these beds of sand and gravel to the chalky Boulder Clay, are found in the cuttings at the ends of the Benniworth tunnel.

FIG. 5.

Cutting in Drift at the east end of Benniworth Tunnel, on the Louth and Lincoln Railway.



One hundred yards from the western end of the tunnel, the chalky Boulder Clay is seen to be 3 to 12 feet thick, resting with a sharply defined base on very fine sand, fine stratified grit, and gravel (Fig. 5). The Boulder Clay is so intensely chalky as to present at a distance the appearance of a white chalk cliff. It contains large striated flints and boulders of chalk, and is quite unstratified. Its base is, generally speaking, horizontal, though slightly undulating; it may be traced all round the head of the Willingham valley and on the other side of the hill at about the same level. The sand and gravel are exposed to a depth of 4 feet, but appear to have a total thickness of about 20 feet, though their base is completely hidden by talus. The sand is fine and buff-coloured, while the grit is made up of minute specks of chalk, flint, and sometimes of the spherical grains of iron oxide from the Tealby beds. In this deposit there occur irregularly shaped masses of brown Boulder Clay of a different origin to the intensely chalky clay above; they contain flints, but are chiefly made up from the Neocomian clays. The position and shape of these masses, and the occasional obliteration of the bedding of the sand and gravel, appear to have resulted from a forcible disturbance, and, perhaps, indicate the intermittent action of ice. Tongues of a similar clay project into the base of the chalky Boulder Clay above, so as to present the appearance of having been dragged towards the south-west. The same clay is seen resting on the Spilsby Sandstone in a sand-pit south of the railway; it is hard and reddish-brown, and contains flint, chalk, red chalk, and blocks of Tealby Limestone.

At the east end of the tunnel the brown clays included in the sand and gravel series are more developed. The base of the intensely chalky Boulder Clay may be seen over the entrance of the tunnel, about 2 feet of it being cut through in this end of the cutting. This is underlain by 12 feet of fine pale yellow sand, interstratified with fine yellow loam or clay, and with some very fine grit, composed of specks of flint and chalk. Below this there appears a blue clay, 10 feet thick, with small chalk fragments, underlain by 6 feet of hard brown clay with chalk. Further down the line a clay with blocks of Neocomian limestone, broken Neocomian fossils, and fragments of shale is seen. It is difficult, however, to state what occurs *in situ* here, and how much is the result of slipping.

On the South Willingham and Donnington road, three-quarters of a mile from the former village, there is a gravel-pit in this same series. Here it consists of loose flint-gravel, with bands of sand and grit, containing abundance of oolitic grains of iron oxide. Very few boulders other than flints occur; but I observed one specimen of a purplish micaceous sandstone, resembling a stained Carboniferous rock. The gravel is about 10 feet thick, and rests on the Neocomian sandstone; up the hill to the east it is quickly succeeded by the intensely chalky Boulder Clay. A short distance to the north the sand and gravel are overlapped by the chalky Boulder Clay, but reappear for a short distance on the north-west side of the valley about three-quarters of a mile north-east of South Willingham.

On the east side of Benniworth Hill the sand and gravel, with the included masses of brown Boulder Clay, run for a long distance at the base of the chalky Boulder Clay. The section at the east of the tunnel has already been described. Four hundred yards north-west of Benniworth Haven, near a barn, there is a small opening showing roughly stratified flint-gravel, grey gritty loam, and grit with thin bands made up almost entirely of oolitic grains of iron oxide. From the nature of the soil, there appears to be much of the brown or blue Boulder Clay in the series hereabouts. Half a mile east of Biscathorpe there is a large pit in flint-gravel in the same series; and, again, near Brough-on-Bain there are exposures of sand and gravel; at Girsby House a sand-pit shows 3 feet of coarse flint-gravel resting on 9 feet of sand, loam, and grit in fine layers, with lines of sharp flint chips and black streaks that may be decomposed grains of coal; the bottom is not seen. The flanks of the low ridge which separates Gayton and Brough are composed of sand and coarse flint-gravel, overlaid by a thin tongue of chalky Boulder Clay. In a pit near Gayton I observed coarse rudely stratified gravel, with thin inconspicuous bands of loam. The most abundant boulders are chalk and flint, but purple sandstone (? Carboniferous), grey granite, basalt, and ironstone nodules also occurred. Near Gayton church, on the road from Biscathorpe, sand and gravel occur again, and give out springs, but there is no exposure. About

one mile west and north of Brough, and at a short distance east of Gayton, the sand and gravel beds thin out against the rising slope of the Wold, thus clearly indicating the close connexion between their distribution and the pre-glacial valley of the Bain.

Some three miles further to the north-east, near Kelstern, there are two instances of sand and gravel occupying a similar position in the northern part of the village; the Boulder Clay generally rests on the Chalk, but near the church a bed of sand intervenes, in which, as I was informed by Mr. Sharpley, a well for Kelstern Hall has been sunk to a depth of 12 feet, and has tapped a good spring. It is probably the same bed that appears for a short distance in the side of the valley, about one mile to the south-east. A similar instance occurs near Binbrook House, near the northern margin of the sheet; a patch of stratified sand, loam, and gravel of very limited extent appears from beneath the chalky Boulder Clay at the head of a small tributary valley.

In addition to these gravels, there occur two instances of gravel-eskers or ridges, not clearly overlaid by the chalky Boulder Clay, but presumably of the same age as those above described. The first is at Binbrook Walk House, about two miles south-east of Binbrook. The gravel occurs here in three patches, one of which extends nearly across the chalk valley in a distinctly esker-like form. There are two gravel-pits in this ridge, one on each side of the road. That on the north side shows the following section:—

	Ft.
Sand, with pale reddish and yellowish loam and fine clay	0 to 4
Bands of fine grit and sand well-bedded, with layers of flint fragments interbedded; the whole firmly cemented into a hard rock, about	2
Coarse flint- and chalk- gravel, with stones well rounded; cemented into a conglomerate; with bands of finer flint fragments cemented into a breccia	20 +

The pit on the south side of the road exposes 18 feet of coarse pebble-gravel, stratified and loose, with one or two thin veins of grit. Some unusually large boulders of chalk and flint occur, and a few of altered micaceous sandstone or quartzite, &c., but the mass is made up of rolled flints.

The second instance of esker gravel referred to above occurs at Panton. The gravel here forms two conspicuous hills on either side of the stream which runs from near Stainton to Wragby. On both hills are large excavations for gravel. A large gravel-pit in the more southern of the two hills shows on the north-east side:—

	Ft.
Unstratified flint-gravel, like much weathered chalky Boulder Clay	10
Alternations of white and brown sand with little loam, the white made up of comminuted chalk, the brown of flint grains with specks of iron oxide; the whole current-bedded	4

The north end of the pit, where alone gravel was being worked at the time of my visit, showed unstratified or very rudely banded gravel, crammed with flints in a gritty brown matrix. This bed, which resembled chalky Boulder Clay in a completely weathered condition, was from 6 to 15 feet thick and rested very irregularly on well-stratified sand, white in parts and made up of chalk, quartz, and iron-oxide grains, and in parts fine and buff-coloured or gritty and brown. In the sand there also occur small flints in lines, and beds of flint-gravel similar to the overlying mass, in one instance the matrix being chalky. The flints in the coarse, almost unstratified, gravel are many of them well striated. There occur with them an occasional pebble of purple sandstone (? Carboniferous) and a few ironstone nodules, and rounded masses of basalt, which under the influence of weather have developed concentric layers, peeling off like the coats of an onion. A few white quartzites also occurred, and an occasional pebble of red granite was noticed by Mr. Cameron, but the mass of the material, as in the case of the gravels previously described, was made up of flints. Though the base of the coarse gravel is uneven, there is no appearance of unconformity between it and the sand; the

stratification of the two may often be seen to be nearly parallel. The total depth of gravel and sand seen is 20 feet.

The gravel-pits in the more northern of the two hills show a section so similar that it is unnecessary to repeat the description.

In both cases these gravel hills occur at the termination of long extensions of chalky Boulder Clay which run down from the great mass to the east. The gravel rises to a greater height than the Boulder Clay, and ends off in a rather abrupt bank facing E.S.E. in the one case, and about E. in the other. The chalky Boulder Clay comes on suddenly at the foot of these banks. The gravel, however, though forming the higher ground, is probably older than the Boulder Clay. The almost unstratified gravel in the upper part of the pit, very closely resembles the gravelly material that results from the removal by weathering of the chalk from an intensely chalky Boulder Clay. Their mode of occurrence is analogous to that of esker-sands and gravels in other parts of England, where hummocks of sand are frequently found rising abruptly through Boulder Clay.

By the side of the road near the pit described are about a dozen large sandstone boulders, and one of volcanic rock; the sandstones are probably of Lower Neocomian age.

A patch of gravel of Glacial age occurs on Imber Hill near Goulsby. A shallow pit on the north-east side shows roughly stratified gravel overlying fine sand with bands of grey loam. The gravel is made up principally of flints and chalk pebbles. Red Chalk, Lower Chalk, and Middle Chalk, and a creamy variety of chalk like some beds in Yorkshire all occur, with rarely a pebble of micaceous quartzite. There are several large blocks of Lower Neocomian sandstone with fossils, and showing the common spheroidal form of weathering, and some smaller fragments of Neocomian Limestone lying about.

This gravel-patch occupies a similar position to that of Fulletby and of Greetham. Their relation to the chalky Boulder Clay is not clear in any case. In the last named it appeared as though the Boulder Clay locally passed into a stratified gravel (Explanation of Sheet 84, p. 73). There is not unfrequently a tendency in the intensely chalky Boulder Clay near the Wold escarpment to become locally gravelly and even rudely stratified, as is seen in the pits on Benniworth Hill, south of the tunnel. In these, the stratification is indicated by the larger stones occurring in beds, and by the interstratification of incontinuous veins of finer chalky material with small chalk pebbles in the coarse gravel; in one of the pits the coarse gravel is capped by 2 feet of chalky loam. The gravel is composed of flints and chalk pebbles varying from the size of a marble to boulders 8 inches long. In one case the chalk-pebbles were so abundant as to be picked out for burning in a kiln erected in the pit. The northernmost pit shows quite unstratified Boulder Clay of the usual type on its north side, and a stratified gravelly deposit on its west side, the 6 or 7 yards separating the two being unfortunately obscured.

A patch of sandy soil occurs on the highest part of Benniworth Hill, north of the tunnel; there are no pits, but coarse brownish grit full of small flint and quartz fragments is thrown out by rabbits, and seen in the ditches and in the sides of the barrows. Judging from its position, it appears to be a gravelly pocket in the Boulder Clay, and of Glacial age, though later than the gravels underlying the Boulder Clay in this neighbourhood.

A similar patch of sand and gravel occurs on Hamilton Hill between Market Rasen and Tealby. It has been worked at the west end of the hill. There also the deposit occurs in such intimate connexion with the Boulder Clay as to be inseparable from it.

Turning now to the western boundary of this sheet of Drift, we find that everywhere the Boulder Clay rests directly on the rock without the intervention of any beds of gravel. On the Oolite hills, however, near Lincoln and near Nettleham, on the western face of the escarpment in the north, and in several places on the Lias and on the Keuper Marl areas, there occur small patches of gravel which there is reason to believe are of

Glacial age. In speaking of these, Mr. Dalton says :—The determination of the age of the gravels, now seen as outlying and isolated patches, is in some cases impossible at the present time, and must be so till the Drift-deposits of the Midland Counties have been studied in detail. The evidence furnished by the deposits themselves is of the vaguest description, consisting of lithological constitution, relative level, and in a few cases topographical proximity. The lithology proves little, since Glacial gravels, and those formed post-Glacially, from the denudation of Glacial gravels, would contain much the same proportion of the various rocks.

Relative level, again, is a matter involving assumptions as to mode of deposition of the beds, which may afterwards prove untenable. River gravels sometimes form wide expanses, level from side to side, and descending only with the fall of the river ; but it occasionally happens that the erosion of the valley has been so gradual, that a broad slope has been formed on one or both sides, the upper parts of which, whilst truly older than the lower, form with them a continuous sheet of gravel, which, if subsequently broken up by denudation would leave patches at various levels, simulating the irregular mode of occurrence of Glacial gravels.

Topographical position has been in some cases the most important point bearing on the age of a patch of gravel. This, in conjunction with levels, has been our chief guide in classing together the gravels of Woodhouse Common, Grove, and Gringley, which occupy similar positions with reference to the escarpment of the Keuper Marl. The first named is undoubtedly Glacial ; the others are by inference of the same age.

a. On the Oolite Range.

In the fields near the new hospital at Lincoln traversed by the path to Greetwell, the removal or decay of the props in the exhausted levels of the ironstone workings has caused the overlying rock to fall in several places, showing the existence of a large patch of stratified gravel consisting principally of Oolite, but with a considerable quantity of quartzite ironstone and Lias. The breaking up of the Oolite pebbles produces a soil very like that of the bare rock, so the limits of the gravel are, in the absence of sections, somewhat indefinite ; but the deposit is terminated southwards by the escarpment, and does not extend much beyond the hospital grounds to the west and north, whilst the rock comes to the surface at the open work not far eastward. The age and origin of the gravel are questions of much greater importance and difficulty. The quartzite pebbles, as will be seen, are not only abundant in the patches of gravel on the Liassic and Keuper Marl areas which are believed to be of Glacial age, but enter very largely into the composition of the low-level post-Glacial gravels, and cannot therefore be taken as a test of age. The level, however, at which these gravels occur (about 150 feet above the bottom of the valley), seems to indicate that they are distinct from the great spread of post-Glacial gravels hereafter described, which keep uniformly to a low-level on the Lias plain. They may be with more probability referred to the period of submergence during the Glacial Epoch, when the escarpment was in part, if not wholly, sunk beneath the level of the sea. The patch of gravel now to be described as seen near Nettleham affords confirmatory evidence.

Half a mile east of Nettleham Hill a singular mound of gravel lies on the termination of a promontory of the Great Oolite series between the Nettleham and Scothern brooks. Its structure is well exposed in a small pit on

the east of the road. At the base is sand, in which was found a large ball of blue clay charged with fragments of sandstone such as the rapid destruction of the Kellaways Beds might yield. The surface of the sand is horizontal, and above it is a mass of angular and sub-angular material, principally derived from the Great Oolite, with the edges of the flat fragments, but little more rounded than they would be by atmospheric action. A few quartzite pebbles, and some bits of sandstone (? Kellaways Rock) were the only rocks not found *in situ* within 200 yards. But the principal point of interest is the dome-shaped bedding of the mass. The component flakes dip outwards away from the hill on all sides, much as in a railway bank composed of broken flagstone, and formed by "tipping" from one end. Wide interstices occur between the flakes, some partially filled with sand and some with tufa, but often quite empty. It is difficult to conceive of the production of such a structure by any fluvial action, but in the conflicting currents which would arise by the submergence of the escarpment to within tidal influence, one may see a possible cause of the stacking of slightly worn flakes of rock at points of comparative quiescence.

W. H. D.

Eastward of Navenby Mr. Penning records the occurrence of traces of old quartzite gravels in several places at some distance from the escarpment and on high ground. The pebbles are thickly strewn over the fields, but unfortunately there are no sections to be seen.

b. Between the Trent and the Oolite Escarpment.

The task of distinguishing the Glacial from the post-Glacial gravels in the low-lying Liassic area south of the Foss Dyke becomes very difficult from the fact of the lithological composition of the two being almost identical. As will be afterwards shown, the distribution of the post-Glacial gravels south of the Foss Dyke lends support to the view that they are old river gravels, laid down by rivers which have since taken very different courses. As a whole, these gravels occupy the lower ground, and form a plain sloping gently down to the north-east. There occur, however, patches of gravel in the same area, which, by their position at a higher level on the tops of the low Lias hills, seem to have had a different origin; among these may be mentioned the patch on the southern margin of the Sheet near the Lincoln and Newark Road, the two patches crossed by this road on Potter Hill between the 9th and 11th milestones from Lincoln, and more doubtfully a portion of the spread which extends from Eagle towards the north-east. The height of the patches on Potter Hill is about 117 feet above Ordnance Datum, or 50 feet above the level of the post-Glacial gravel of the neighbourhood. They thus appear to be more nearly related to the gravels which occur on the escarpment, and on the Keuper Marl area, west of the Trent.

Further north, several patches of sand associated with gravel have been observed by Mr. Ussher, who makes the following remarks:—

Their relations to the surrounding Boulder Clay are nowhere exposed in section, but from their position they appear to rest upon it. There are three of these patches near Corringham, two south of Upton, and one at Willingham which may be an outlier of the same deposit.

Besides these, there are masses of sand which may either rest on, or occur in, the Boulder Clay. One of these extends from near Pilham southwards for about a mile and a half, there being surface evidence of its presence along a slight slope. It may be a patch on an eroded surface of the Boulder Clay, and contemporaneous with, or derived from, the Corringham gravels, or a lenticular bed in the Boulder Clay. A short distance to the south a patch of pale-brownish sand, probably of Glacial age, partially conceals the Boulder Clay west of Till Leas Common. Another large patch of sand, 2 to 4 feet in thickness, conceals the Lias north of Sturton; this may be an old river deposit.

Of the patches at Corringham, the northernmost is principally sand at Aisby, but to the south-south-east of this village a large pit, now much overgrown, shows gravel of worn fragments of grit and quartzite, Lias limestone, nearly angular chips of flint, coralline limestone (? from Derbyshire), and

granitic rocks; the larger fragments are imbedded in a finer gravel of similar materials, associated with coarse earthy sand and apparently overlaid by, and irregularly intercalated with, reddish sand. In the southernmost of these patches, near the turning to Corringham Church, a pit exposes fine-grained light-red sand, with no apparent bedding. In one part of the pit gravelly *débris* of worn grit, quartzites, and flint rest irregularly on the sand; but the section is much overgrown. The third patch east of the church is very ill-defined.

The Upton and Kexby gravel patch has been worked in a pit now mostly grass covered, but showing 5 to 10 feet of gravel of Lias limestone, grit, and quartzite, angular or well-worn. Nearer Kexby a pit exposes 5 feet of pale reddish and brown sand, with reddish markings resembling bedding-planes. The sand in one spot appears to contain a lenticular seam of brown clay; no foreign fragments were found in it.

W. A. E. U.

c. West of the Trent.

The gravels of the southern portion of this tract are described by Mr. Dalton as follows:—

The only case on the western side of our district in which gravel is unmistakably overlain by Boulder Clay is that of the ridge between Woodhouse Common and Kersall Lodge. On the north of the Lodge is a large pit furnishing the subjoined section:—

	Ft.
Stiff red-brown Boulder Clay, mottled with grey, rather scantily interspersed with angular, sub-angular, rounded, and glaciated boulders of various rocks	2 to 6
Yellowish pink sand with streaks of broken coal; in the upper part are pockets of gravel, which merge with that below, leaving mere lenticular masses of sand, which at most is but	4
Gravel, mostly of quartzite pebbles, but containing some of sandstones and limestones, pieces of hard shale slightly worn. No chalk flints were visible, but there is a considerable proportion of Liassic and Oolitic rocks	8
Red Marl (Keuper).	

The stones in the Boulder Clay are principally of Magnesian Limestone. The following is a list of all the varieties noticed:—

1. ANGULAR.	3. ROUNDED, NOT STRIATED, FROM BUNTER.
Lias limestone.	Quartzite.
	Vein-quartz.
	Slate.
2. SUB-ANGULAR.	4. ROUNDED, STRIATED.
Magnesian Limestone.	Chalk.
Oolitic ragstone.	White Lias limestone.
Triassic sandstone.	Carboniferous Limestone.
Carboniferous sandstone.	

To the east of the Lodge are two large ploughed-down pits whence gravel has been raised, and at Beacon Pits on Woodhouse Common, are a number of small shallow excavations in reddish sandy gravel, which may attain, but certainly does not exceed, 6 feet in thickness. The road-metal raised from these and the Kersall Lodge pit yields, besides the varieties named, occasional small pebbles of a fine-grained granitic rock, apparently derived from the same source as the quartzite pebbles, which they resemble in their degree of attrition.

Five patches of gravel, presumably of Glacial age, cap the hill north-eastward of Grove. In the more westerly of these a small pit near the "Castle

Moat" shows about 6 feet of rather coarse gravel, consisting principally of well-rounded quartzite, vein-quartz, slate and other Palæozoic rocks, apparently derived from the waste of the Bunter beds. With these occur pebbles of Carboniferous chert and sandstone, felspathic tufts, flints, two or three varieties of basalt and of granite, and streaks of coal débris. From a trench near by was thrown out a large pebble of coarsely-crystalline granite of pinkish grey matrix, with dark prismatic crystals. The eastern side of the patch consists of crimson and tawny sands with fine gravel. In the small patch north of this are large masses of basalt, well-rounded on the edges, but retaining traces of their original angular outline.

W. H. D.

Mr. Cameron notes also a boulder of coarse grit, measuring 6 feet by 4, near the top of the hill, and remarks that the cluster of gravel-patches give rise to several streams flowing eastward to the Trent near Yorksey.

The patches of sand and gravel at Gringley-on-the-Hill are presumed to be of Glacial age, from the fact of their occupying a corresponding position to those of Woodhouse Common and Grove. They have been mapped by Mr. Ussher, and are described by him as follows:—From the turnpike at the west end of the village to near Gringley Grange on the east, the highest ground between the alluvial flats of the Trent and the Idle, is capped by a patch of sand at an elevation of 275 feet above the sea. Towards the west end of the patch, and at the turning toward Gringley Wharf, the sand is gravelly, and a boulder of very fossiliferous crinoidal limestone measuring $4 \times 3 \times 2\frac{1}{2}$ feet, and now standing by the Registrar's house, has probably been derived from it. The loamy soil extending towards the east beyond the limits of the patch of sand suggests the further extension of this patch in that direction.

The former greater extension of the Gringley Hill sand is proved by the presence of patches of loamy soil with pebbles. These patches have been indicated by a note on the map, but are not distinguished by colour. Pebbles are scattered over the surface of the hill upon which Wheatley Grange Farm is situated, and a boulder or two of quartzose grit appear to be almost *in situ* at the farm. Loamy soils with a few pebbles occur east of Walkeringham, between this village and Gringley, and at the head of the stream south of Gringley Grange; a large tract occurs between Gringley and Clayworth, and a similar soil is found on the hill north of Merry Cock Hall. In addition to these indications, outliers of the deposit are found severally two miles east, one and a half miles north-east, one mile south-west, and one and a half miles west, of Gringley. The last-named is shown in a pit by the high road to consist of a yellowish-brown sand.

W. A. E. U.

Boulder Clay.

The Boulder Clay here as elsewhere attains its greatest development in the low ground. At the close of the Glacial Period it appears to have extended continuously from the Oolite hills on the west over the almost featureless plain of the Oxford and Kimeridge Clays. On the east its limits were for the most part determined by the bold escarpment of the Chalk. But a similar deposit is found here and there mounting the escarpment and spreading out on the high wold country up to a height of about 500 feet. The pre-Glacial valley of the Bain, for example, formed a break in the hill side, up which the low-level clay runs so as evidently to have once joined on to the high-level sheet, though now separated from it by the modern valley cut by this river. The gently inclined plane formed by the Drift of the low ground has been converted into a slightly undulating tract by a number of eastward flowing becks, most of which have cut their way down to the underlying rock.

In the neighbourhood of the Wolds the Boulder Clay is composed of little more than re-arranged chalk. The boulders are chalk-lumps and flints usually well-glaciated, and the matrix is a stiff white paste of ground-up chalk. Passing away from the Wolds in a southerly or westerly direction this intensely chalky clay passes imperceptibly into a pale blue or lead-coloured clay with fewer chalk-lumps and flints, and with an increasing proportion of blue clay derived from the Neocomian and Kimeridge Clays in the matrix. A line drawn from Mareham-le-Fen through Roughton, Woodhall, Wispington, Minting, Panton, East Barkwith, and round the slopes of the hills on which Hainton and Sixhills stand, indicates approximately the southerly and westerly limits of the intensely chalky clay. It will be observed that this type of Boulder Clay, which has clearly been derived from the Lincolnshire Wolds, extends further in a southerly than in a westerly direction from its source. For example, the clay in some pits a quarter of a mile north of Mareham-le-Fen church is described by Mr. Skertchly as being almost entirely composed of chalk with many large unworn flints, the chalk occurring in all states from a fine powder to large rounded boulders a foot square, and nearly every fragment being ice-scratched. Many of the flints are large and unworn, retaining their cherty coating, which is always striated. Other rocks noticed were fragments of Coal-Measure sandstone, quartzite, greenstone, and nodular lumps of dark blue Kimeridge Clay. Near Horncastle again the clay is of the intensely chalky type, with very few boulders other than chalk and flint, to a distance of eight or nine miles from the Wold. But near Sixhills the breadth of this deposit rapidly diminishes, the less chalky clay running nearly up to the Wold foot. From this it may be inferred that the direction of transport of the Boulder Clay was from north to south, an inference that is borne out by the distribution of the other Glacial Deposits.

The Boulder Clay, as it rises on to the higher ground in the neighbourhood of the Wold becomes more stony, as previously remarked. As a general rule, the matrix is a tough white clay composed of ground-up chalk, the flints and boulders of chalk being distributed irregularly throughout the mass. There may, frequently, however, be observed a rough stratification, the larger boulders being prevalent along certain lines, as in the pits on Benniworth Hill previously alluded to (p. 125). The action of weather on such a deposit is to remove in solution the chalky constituent, leaving a roughly stratified gravel which can hardly be distinguished from that which underlies the Boulder Clay. In the former, however, scratched stones are usually found, while in true esker-gravels they are rare or absent.

In proceeding from south to north the first occurrence of Boulder Clay on the Wold escarpment is found east of Biscathorpe. Here the bold features of the Red Chalk and Carstone are lost for a short distance under a patch of chalky Boulder Clay of the usual Wold type. The deposit is unstratified and full of scratched

chalk and flint-pebbles. It rests on a slope in which the various beds of the Chalk and Neocomian rocks crop out in succession; the slope is gentle and not comparable to the cliff-like scarp which bounds the Wold southwards. The mode of occurrence of this outlier gives strong support to the view that the Boulder Clay formerly extended continuously from the plains up to the Wold scarp southwards, by Stenigote and Cawkwell and over the present site of the Steeping Valley (Sheet 84). The present limit of the Boulder Clay on the Market Stainton, Scamblesby, Fulleby, and Greetham Hills is obviously the result of the post-Glacial excavation of the valleys of the Bain and Steeping.

The outlier of clay at Biscathorpe, and the gravelly patch on Imber Hill, belonging to the same series, occur on about that level which would be attained by a continuous slope extending from Market Stainton to the face of the escarpment, and are without doubt relics of a sheet once continuous up to the edge of the Wold.

This intensely chalky Boulder Clay was much used in former times for marling land; but the old pits are now mostly overgrown, and the only sections occur in the banks of the streams. Some good exposures may be found in the banks of the Bain below Horncastle. Above this town the river-bed is in Kimeridge Clay, but at the Railway Station a boring put down by the Great Northern Railway Company passed through 44 feet of Boulder Clay before reaching the Kimeridge Clay.*

One-third of a mile south-south-east of Panton House there is a limekiln in a pit showing about 12 feet of soft white marl, with very few stones, resting on a blue clay which appears to be the disturbed surface of the Kimeridge Clay. In general character this white clay or marl may be taken as a type of the Drift of Minting and Sturton. Boulders as compared with the neighbourhood of the Wold are rare; flints and chalk being the most abundant, but Neocomian Limestones being also present; I observed also one specimen of white micaceous quartzite. North of the railway, in the Boulder Clay that caps Benniworth Hill, boulders of Neocomian Limestone become more abundant. It may be noticed that this occurs just to the south of the localities where the limestone is best developed.

Similarly in the neighbourhood of Langton, near Horncastle, there are several large boulders of Lower Neocomian Sandstone, which also appear to have travelled from north to south.

Returning to the neighbourhood of Benniworth, we find the Boulder Clay extending up the slope to the outcrop of the Red Chalk in the neighbourhood of the "Heneage Arms." East of this spot it has been cut through by two of the tributaries of the Bain, but on the north it comes on in force on the top of the Wold in the immediate neighbourhood. Thence it extends in a long tongue eastwards by Wykeham and Calsthorpe, sending a long arm towards Biscathorpe on the top of the ridge of sand and gravel which runs between Brough and Gayton. Eventually rising to some of the highest ground in Lincolnshire about Lambcroft, it passes from the Sheet in a northerly and easterly direction. It will be seen that though not actually continuous with the Boulder Clay of the plain, this high-level clay is only separated from it by small narrow valleys of obviously post-Glacial origin; it is, in fact, the same deposit that extends from the highest part of the Wold down to below the sea-level.

There are many old marl-pits in the Boulder Clay on the Wold, but they are now ploughed over, and difficult to distinguish from old pits in the Chalk made for the same purpose; they usually contain water, the chalk-pits being generally dry. A pit about one mile west-north-west of Julians Barn near Kelstern shows 4 to 6 feet of a chalky clay with flint and chalk boulders, not

* See Appendix, p. 205.

large or very numerous, resting on a broken and uneven surface of Chalk in place.* Two furlongs west of Julians Barn, Mr. Jukes-Browne observed about 10 feet of yellowish-grey clay overlying a rubble of broken chalk. At the northern margin of the Sheet there is a thin gravel on the Boulder Clay that has been worked for road metal. It appears to be the result of the long continued action of weather on the intensely chalky Boulder Clay. The small patch noted by Mr. Jukes-Browne half a mile east of Lambcroft Walk House may have had a similar origin.

About Willingham and Hainton the intensely chalky Boulder Clay is based by a lower clay made up chiefly of Neocomian *débris* with great boulders of Neocomian sandstone and limestone, as hereafter described. The relations of this lower clay to the gravel on which the intensely chalky clay rests further to the east, are not clear. In appearance it resembles the masses of clay included in the gravel, but as a rule the clay comes in at about the point where the gravels thin out. It is not possible to divide the white from the blue clay; though clearly distinguishable in some places they insensibly merge one into the other westwards.

The same sequence may be observed about Sixhills and Hainton. The intensely chalky Boulder Clay here rests on a basement clay, yellow or sometimes bluish, with fragments of chalk, flint, Red Chalk, and Tealby Limestone, the matrix being principally of Neocomian clays. The junction between the two clays may be easily traced round the flanks of the hills. It seems likely that the intensely chalky Boulder Clay of Sixhills and the neighbouring outliers to the south must have been continuous with the mass of similar clay that covers the Wold south of Ludford, and comes down as far as the outcrop of the Red Chalk. It appears that this is about the limit of this type of the Boulder Clay in a north-west direction. The mass of the Boulder Clay of the neighbourhood of Market Rasen is not of the intensely chalky type, but is largely made up of Kimeridge and Neocomian Clays. A few small outliers hanging on the slope of the scarp about Tealby and Walesby alone approach this type; but their existence is inferred rather from the gravelly nature of the soil and the form of the ground than from any sections.

It should be understood that by the "intensely chalky clay" here mentioned is meant a clay made up almost exclusively of chalk and flints, and which is in section as white as chalk itself. The term "Chalky Boulder Clay" has been applied, by Mr. S. V. Wood and others, to a deposit that may be principally made up of other rocks, but contains chalk in fair abundance. The intensely chalky clay described above is a patch of limited extent, trailing round the south end of, and derived from, the Lincolnshire Wolds; whereas the Chalky Boulder Clay covers wide areas in the eastern counties. As before stated, the one is to be considered a local modification of the other.

Leaving now the area of this local deposit, we find nearly the whole of the plain extending to the rising ground of the Oolites overspread by a blue or lead-coloured stiff clay, with a few stones scattered through it. The boulders are principally derived from the Cretaceous and Oolitic rocks, but a few far travelled pebbles of basalt, Carboniferous Limestone, and granite also occur. Chalk is everywhere present, but in decreasing abundance in the parts furthest from the Wold.

In this clay, also, there may be observed lithological changes as it passes from one outcrop on to another of the underlying

* Close to this pit a good specimen of a Neolithic "strike-a-light" was picked up. They are not uncommon on this part of the Wolds.

rocks. While dark-coloured in the Kimeridge and Oxford Clay areas, and scarcely distinguishable from these rocks except by the presence of foreign fragments, on passing into the neighbourhood of the Neocomian Clay it assumes the paler tint, and yellow or brown colour of this bed, as has been noted about Sixhills.

In the Liassic area north of Lincoln, also, changes in colour in the Boulder Clay have been noticed by Mr. Ussher, depending in part, as he believes, on the nature of the underlying rock (p. 138). He does not, however, conclude on these grounds that there is more than one series of Boulder clays in that neighbourhood. A different age has been assigned to the clay in the valley south of Stow Park, on further evidence (p. 143).

That two series of Boulder Clays, however, of different ages do exist within the area of this Sheet is believed by Mr. Jukes-Browne.* Some reddish-brown and grey clays in the Ancholme-valley (p. 141), though scarcely presenting the usual features of a Boulder Clay in this Sheet, are considered by him to be of Glacial age, on the strength of their appearing to link on to clays of a Boulder Clay aspect further north (Sheet 86). These he correlates with the Hessle Series, which overspreads the ground on the east side of the Wolds, and, arguing from their position in a valley cut through the chalky Boulder Clay, refers to them as "the Newer Glacial Series."

Again, in the railway cutting between Wickenby and House-on-the-Hill, about Linwood, and Faldingworth, Mr. Jukes-Browne has noted the occurrence of a reddish-brown clay, which, he states, caps some of the hills of the greyer Boulder Clay like the relics of a later deposit (pp. 140, 141). A similar clay has been observed by him on the west margin of the Witham fen below Lincoln (p. 137). This clay also is considered by Mr. Jukes-Browne to be the equivalent of the purple and Hessle clay series.

For this view, and for that on the age of the reddish-brown clays of the Ancholme valley, Mr. Jukes-Browne is solely responsible. Up to the present it has not been found possible to draw any line between the reddish-brown clay of these localities and the more usual greyish-blue Boulder Clay; the boundary between the two is so indefinite as to indicate the probability of the one type passing up into the other, the change being merely due to such slight differences in composition or weathering as are common in Boulder Clays. In this, as in other cases of two types of Boulder Clay occurring in juxta-position, the line of separation though well-marked in one locality becomes extremely indefinite in another.

The following observations on the principal sections in the chalky Boulder Clay of the southern part of this Map have been furnished by Mr. Jukes-Browne:—

Boulder Clay comes to the surface round Park House one mile S.W. of Kirkby-super-Bain, and Mr. Patchett, the occupier, states that a bed of sand is sometimes found in or below the Boulder Clay from which a water supply is obtained (*see* Appendix, p. 205).

* *Quart. Journ. Geol. Soc.* vol. xli., page 114, and the *Geology of part of East Lincolnshire* (Geological Survey Memoir), p. 76.

About a mile west of Park House there is a large pit whence clay has been dug for spreading on the land; the section seen here in 1878 was as follows:—

	Ft.
Black soil underlain by white sand	1
Soft brown sand and sandy loam	2 to 3
Dark bluish-grey Boulder Clay	4 to 5

I was told that the clay had been dug to a depth of 19 feet when many large septaria were met with. Possibly the bottom may have been in Kimeridge Clay.

Boulder Clay is also seen in a pit at Fox Hill capped by a few feet of loamy sand, pipes of which descend into it. To the northward the ridge of Park House and Fox Hill communicates with the narrow strip of clay which separates the quartziferous sands of Kirkby Moor from the flinty sand and gravel of the Bain valley.

The Boulder Clay in Braken Wood, near Woodhall Spa, is of a mottled grey and buff colour, and contains chalk pebbles and septaria from the Kimeridge clay.

North-east of Reedbeck there is a pit in clay which may belong to what I have termed the newer division; it is mottled grey and buff, and contains very few stones, no chalk at all, and yet looks like a Boulder Clay. The same clay extends under Waterloo Wood.

At Horsington the upper part of the Boulder Clay only contains small bits of chalk about the size of peas, while the lower part has large chalk stones and boulders of other rocks with fossils from the Kimeridge Clay. Both are dark grey clays, but in the Rectory well the lower is rather lighter in colour, the upper being in some places nearly black.

Boulder Clay is seen in the pits one mile south-east of Kirkstead; it is a dark blue clay mottled with grey, and is chiefly constructed from the material of the Kimeridge Clay. It contains small pebbles of chalk-flint and white quartz with fragments of *Serpula tetragona* and other Kimeridge Clay fossils.

A. J. J. B.

Mr. Skeretchly, in describing Boulder Clay in a pit on the Church Farm, 15 chains south-south-east of Kirkstead Church, says: "The clay is dark blue, but greenish towards the top, where the frequent occurrence of flints and striated chalk-boulders make its glacial character very apparent; lower down, however, these are less abundant, and the frequent scattered septaria make it closely resemble the Kimeridge Clay. On digging into it, however, striated and rounded pebbles of chalk, flints, and pieces of Lincolnshire Limestone are found, and the clay is seen to be compact with rounded fragments of laminated clay, like clay-pebbles, strewed profusely through the mass. A pebble of Keuper Marl was also found, and *Gryphæa incurva* was not uncommon."

The pits at Haltham, Toft Hill, Roughton, and Woodhall Church are in blue clay, with fragments of Kimeridge Clay fossils.

The Boulder Clay is overspread along the fen-border in this neighbourhood by post-Glacial gravels, but further to the north is exposed at intervals in the slopes between these deposits and the fen. A clear section was exposed in a siding at Bardney Station in 1883, showing a very stiff blue clay with numerous pebbles of chalk, and a few of Oolite and sandstone, most of the boulders being scratched. The clay was overlaid by a foot or two of rainwash with quartzite pebbles, but no quartzite pebbles occurred in the clay itself. The brick-pit near the station shows that the Oxford Clay comes close up the level of the fen. It is overlaid here by 4 to 5 feet of rearranged clay with nests and pockets of sand and fine gravel (possibly a relic of Glacial Deposits), the whole section being as follows:—

Bardney Station Brickyard.

	FEET.
Peat, principally made up of wood and containing numerous large trunks of oak and birch	2 to 3
Silt and sand in occasional patches, sometimes gravelly, and containing quartzite pebbles	0 to 3
Blue clay, with a few scratched stones and irregular pockets of sand or fine gravel	4 to 5
Oxford Clay.	

A better section of the Boulder Clay typical of this neighbourhood is found in the Bardney Common brick-pit, of which the section is given on p. 151. In this pit the clay is very stiff, dark-coloured, and nearly stoneless. Chalk, Oolite, sandstone, basalt, and Carboniferous Limestone have been picked from it by the workmen.

The clay about Gauthby is of a similar character, but eastwards soon passes into, or partly under, the intensely chalky type of Drift, which has been already described. Near Panton there is a considerable area of bare Kimeridge Clay, and about a quarter of a mile south-west of Panton House, a newly-opened clay-pit showed a clay made up of small angular fragments of shale from the Kimeridge Clay jumbled up together. A few small fragments of flint occurred in the soil, but there were no foreign stones in the solid clay, which may therefore be considered to be the disturbed surface of the Kimeridge Clay. It is this rearranged shale and clay that passes up into the Boulder Clay of this district, and makes the boundary of the latter so difficult to follow.

About West Torrington and New Collar a yellow and brownish tint partly replaces the blue of the Boulder Clay, and fragments of ironstone and limestone from the Oolites and of *Gryphæa* make their appearance.

In the railway cuttings west of South Willingham there is seen blue and brown Boulder Clay with large boulders of Lower Neocomian Sandstone, some of which are more than 6 feet long; the same bed, with a great boulder of limestone, occurs on the east of this village, and in a sandpit about 500 yards east-south-east of South Willingham Station, where it consists of a very hard reddish-brown clay containing flint, chalk, and Red Chalk fragments and blocks of Neocomian Limestone. This is overlain in the higher part of this and the neighbouring hills of Hainton and Sixbills by the intensely chalky type of Boulder Clay, the boundary between the two being fairly distinct here, but becoming very obscure further away from the Wold towards the west. The two kilns marked on the map, one mile east and north-east of Barkwith respectively, appear to have been in this clay, but are now overgrown. There was formerly a pit a quarter of a mile south-east of Wragby, reaching the Kimeridge Clay through a small thickness of Boulder Clay. A boulder of Lower Neocomian Sandstone more than 7 feet across lies in the old excavation.

The Boulder Clay exposed in a pit on Linwood Warren, near Market Rasen, is of a mottled red, blue, and yellow colour, and contains a few flints. In the railway cutting about $1\frac{1}{2}$ mile further east it is blue and grey, being very chalky in places. It is here about 4 to 5 feet thick, and rests on Kimeridge Clay.

Mr. Jukes-Browne continues the description of this district as follows:—

Three-quarters of a mile west-south-west of Middle Rasen is a small pit which shows about 4 feet of light grey Boulder Clay full of chalk and flints, with larger blocks of Oolitic limestone; one of these, seemingly of Cornbrash, lay in the pit and measured $3 \times 2\frac{1}{2} \times 1\frac{1}{2}$ feet, a very hard square-shaped mass. The Boulder Clay rests on clean blue clay with a layer of septaria full of *Serpulæ*.

Similar Boulder Clay and its junction with the underlying Oxford Clay may be seen in the roadside ditches three-quarters of a mile north-west of West Rasen Church and the same distance east of Bishops Bridge.

Kingerby Spa is a chalybeate spring which seems to issue from the base of a lenticular bed of sand which here intervenes between the Boulder Clay and the Oxfordian.

The south part of North Owersby stands on sand and gravel which appears to be intercalated between the masses of Boulder Clay that occur to the north and south of it, and to probably thin out rapidly to the northward. One furlong south of the church, at the back of the blacksmith's forge, there is a pit in clean yellow sand, and at the four cross-roads to the east there are old pits where the banks consist of greyish and yellowish Boulder Clay, while on the pit-floor small holes had been dug in yellow sand, which must therefore underlie the clay. Half-a-mile south-east of the church there is a small pit whence gravel is said to have been obtained. Along its southern edge the sand seems to rest on Boulder Clay.

A. J. J. B.

On the west side of Langworth Beck, near the Witham, the western boundary of the great sheet of Drift is shown by Mr. Dalton as running by Cherry Willingham, Reepham, Scothern, and Dunholme, with a line of outliers generally separated from it by the escarpments of the Kellaways Rock and Cornbrash, but here and there overspreading these beds. The bulk of the materials of the clay were observed by him to have been derived from the Oolites, but there was a considerable proportion of chalk (much larger than on the west side of the Oolite range), and of boulders of Palæozoic rocks.

The description of this district is continued by Mr. Ussher as follows:—In the Oolite districts on the west of the Ancholme valley, and north of the village of Spridlington, true chalky Boulder Clay is confined to the Oxford Clay areas, though there are indications of glacial action as hereafter mentioned upon the dip-slopes of the Cornbrash and of the Great Oolite Limestone also. East of Glentham and Bishops Norton the Boulder Clay overlaps the Oxford Clay and passes on to the Kellaways Rock.

The Boulder Clay, as a rule, caps the highest part of the Oxford Clay districts, so that it occurs north of Spridlington in isolated patches, the continuity of the sheet having been broken by the valley of the Ancholme and its tributary streams. To this comparatively elevated position there are, however, a sufficient number of exceptions to justify one in concluding that the Boulder Clay sloped from west to east, that is, towards what is now the Ancholme valley. Thus we find the Chalky Boulder Clay of East Firsby north-east of Spridlington, and that to the east of Saxby and Owmbly respectively, descending gentle slopes to the margin of the Alluvium of the Ancholme or its tributaries. These cases, it should be mentioned, are confined to the higher reaches of the Ancholme valley. From Normanby, northwards, we cannot find a parallel, unless it be between Harlam Hill and Sandhays, where Oxford Clay, on, or near the margin of, the Alluvium is overlain by a thin capping of presumably Chalky Boulder Clay.

At the foot of the Kellaways Rock escarpment we do not always find that clear surface evidence of its outcrop which we might expect from so characteristic a rock as the Cornbrash. Although this may be due in some cases to *talus* of Kellaways Rock, there are others where it is not so readily accounted for. South of Sandhays, east of Bishop's Norton, there appears to be a narrow strip of Boulder Clay at the foot of the dip-slope of the Cornbrash, and beyond the limits of this patch foreign fragments are mixed with the local *débris* on the dip-slope. Just north of Glentham the Cornbrash seems to be concealed by a small patch of Boulder Clay, and further south its whole slope appears to be covered by a Boulder Clay soil. East of Caenby the Cornbrash dip-slope may also have been ploughed up by ice, but as the clay exposed on it may be in part at least an exposure of Great Oolite Clay, it has not been shown as Boulder Clay.

A patch of Boulder Clay on the east and south of Low Walk Wood conceals the Great Oolite Limestones and obscures their relation of the Upper Estuarine Series. From the valley east of Caenby Hall to West Firsby, Boulder Clay or Drift-soils obscure the junction of the Great Oolite Clays and limestones, more particularly west of Owmbly.

The Boulder Clay consists of pale bluish-grey clay weathering buff or brownish, and containing numerous fragments and pellets of chalk and pieces of flint.

W. A. E. U.

The Boulder Clay which separates the fen of the Witham from the Oolite range south of Lincoln was mapped in the southern part by Mr. Jukes-Browne, and in the northern by Mr. Dalton. It forms a continuation of that deposit which has been described in the Explanation of Sheet 70 as bordering the western margin of the Fen-land, and which is considered by Mr. Jukes-Browne

to be referable to the Purple and Hesse series of East Lincolnshire. The Boulder Clay of Timberland and Martin is stated by him to closely resemble that of East Lincolnshire. It has not, however, been found possible to draw any line between this and the type of Boulder Clay that overspreads the low ground on the opposite of the Witham, probably in consequence of the one shading imperceptibly into the other. The following observations are by Mr. Jukes-Browne:—

The base of the Boulder Clay is seen in the brickyard east-north-east of Timberland. The Boulder Clay here is dark-grey, mottled with yellow and brown, but its lower part seems to pass down into the Oxford Clay below, the upper part of the latter being disturbed and kneaded up into the Glacial clay. The line of separation can, however, be distinguished from a little distance, and the workmen recognise the difference from the strings and veins of sand which occur in the Boulder Clay, as well as by the occasional stones and boulders. Some of these are of large size, one fine block of gneiss measuring $3 \times 2 \times 1\frac{1}{2}$ feet; two others of Marlstone rock full of *Terebratula* and *Rhynchonella* were also observed.

The Boulder Clay is covered by late post-Glacial deposits, and the section near the west end of the pit is as follows (1878):—

	Ft.
Soft silty clay or warp	4
Thin layer of peat	0 $\frac{1}{4}$
Occasional potholes of sandy gravel	—
Mottled Boulder Clay	5 to 8
Clean slate-coloured Oxford Clay	5 to 2

Eastward, the Boulder Clay is cut out by the gravel for a space, as shown in the figure and description on p. 171.

A clay-pit in Martin Wood, some 100 yards south of the end of Timberland Delph, shows the following section:—

	Ft.
Dry brown crumbling clay with small chalk pebbles	3
Sandy clay with pebbles of flint and quartzite	1 $\frac{1}{2}$
Dark mottled brown clay with sandy veins and patches containing pebbles of chalk, flint, quartz, and quartzite	3

In a field south of Martin, and north-west of Martin Wood, there is a chalk pit, or rather a pit excavated in an enormous boulder of chalk. As far as this boulder was exposed at the time of my visit in 1878, it measured some 20 yards square and was from 7 to 8 feet deep. It is placed almost horizontally, and the bedding is marked by layers of pale grey flints, but it is strained and bent so as to dip slightly in different directions. The flints prove it to have come from the Middle Chalk of Lincolnshire, the nearest part of which is 16 miles to the north-east of Martin. At the south-east corner of the pit a large lump of dark grey Boulder Clay is included in the crushed chalk. At the north-west corner the chalk is overlaid by dark clays, as below:—

	Ft.	In.
Wash of quartzite gravel	1	0
Soft silty clay passing down into brown laminated clay	1	3
Layer of small pebbles, chalk, flint, &c.	0	3
Dark brown and purplish Boulder Clay	1	6
Chalk, nearly horizontal	7	0
	11	0

A. J. J. B.

The Boulder Clay of this tract is further described by Mr. Dalton:—It rises as a bold hill above the plains of Oxford Clay on the west, separating it from the fen. North of Dunston it feathers away on the surface of the various members of the Oolitic series with a less sharply defined boundary. At Dunston Station the levelling of the yard around the Goods Shed in 1882 revealed a finely glaciated floor of Lincolnshire Limestone, polished and striated in lines bearing W. 42° N. and N.W.* A portion of this being above the desired level was quarried away, the remainder south of the Goods Shed being left with its covering of Boulder Clay below the road metal. Over the rest of the yard the Boulder Clay was found to be of varying thickness up to 15 feet, and to contain boulders of various members of the Oolitic series.

W. H. D.

West of the Oolite Escarpment.

The Boulder Clay on this side of the escarpment was mapped by Messrs. Dalton and Ussher. In speaking of the southern part of the Boulder Clay tract, Mr. Dalton says:—

A sheet of Boulder Clay, thinly covering the Lias (which is revealed along valley slopes) lies against the escarpment of the Marlstone from near South Carlton to Ingham, extending westwards to the low ridge of Liassic sands at Broxholme, to the top of which it rises at Pill Bridge. North and west of Coates its mode of occurrence is too irregular for verbal description, but indicates its former extension westwards as far as, and in some places beyond, the Rhætic escarpment. In the area south of Ingham, it consists of a stiff red, blue-mottled clay, with minute grains of chalk and Keuper Marl sparingly disseminated through it. The quartzite and other pebbles scattered over the fields, alike on the Boulder Clay and on the otherwise bare Lias clay, are probably of later post-Glacial transport.

W. H. D.

The northern part of this tract of Boulder Clay was mapped by Mr. Ussher, by whom the following observations have been made:—

From Ingham the Boulder Clay extends continuously northwards to Heapham, and to the northern margin of the Sheet between Blyborough and Pilham, spreading westwards from the foot of the Oolite escarpment to Thonock Camp, Somerby Hall, and Springthorpe, with outliers at Upton, Wharton Wood, and near Lea Station. On the east it conceals the junction of the Lower and Middle Lias; on the west it overspreads the Rhætic near Thonock Camp, north of Lea Station, and at New Park House, south of Lea Station, being itself in the two last-named localities much covered by sand. The lower beds of the Lias are also concealed by an irregular patch of Boulder Clay, north of Stow Park Station.

The composition of the Boulder Clay in the Lias districts is by no means homogeneous, and although most of it is strictly chalky Boulder Clay, there is much to which that term cannot properly be applied; yet there is no evidence of more than one series of Boulder Clays in this neighbourhood.

The Boulder Clay between Lea and Marton Stations is brownish, partly stiff, partly loamy, with bits of flint and worn foreign fragments, mostly grit (probably Carboniferous). Near Kexby and Kexby Mill the Upton patch terminates with brown clay, containing bits of flint, Lias limestone, &c. Near Thurlhy Wood House, brown and reddish Boulder Clay, mottled with grey, and containing small white chalky fragments, occasional pieces of Lias lime-

* Slabs of the glaciated floor are preserved at the Ladies' Training College, Lincoln, and in the Museum of Practical Geology, London.

stone, and of worn palæozoic grits, is exposed to a depth of 5 feet; the clay is both sandy and gritty in places. About one mile to the east, by the road to Heapham, some pits now overgrown had been opened apparently to obtain the boulders for road metal.

Near Heapham and Heapham Mill the Boulder Clay makes a brown loamy soil, and on the east of Heapham and Springthorpe is represented by a stiff clay, with large and small pieces of flint and worn grit. To the south it is more loamy in places. Grey and reddish Boulder Clay is shown under the Alluvium at Turpin Farm, and in the ditches about Rectory Farm to a depth of 5 to 8 feet; east of Glentworth Low Cover the Boulder Clay is brown and veined with grey.

West of Glentworth purplish Boulder Clay occurs; it is exposed by a new road three-quarters of a mile west of the church. It is mottled with grey and contains small pieces of flint, very large boulders, apparently of Liassic and Oolitic rocks, and a large chalk-pebble. In one place the Lias is exposed beneath it. There is evidence of a similarly coloured clay west of Blyth Close. Typical grey chalky clay is found further to the west, near the farm south-east of Harpswell Wood, but near St. Peter's Wood, and in the stream to the east of it, mottled red-brown and grey clay occurs. To the north again, by Harpswell Lane, there is evidence of bluish-grey Boulder Clay, and between Magin Moor and Corringham, of stiff brown clay.

The hill on which Somerby Hall stands is capped by reddish and bluish-grey clay, and at the bend in the high road east of Towland Lane House, there has been excavated a reddish and grey mottled clay, with fragments of Lias scarcely worn and occasionally of large size; the presence of chalky grains and pellets renders the clay gritty in places.

The extension of the Boulder Clay westward towards Thonock Camp is doubtful; it seems to be very loamy, and the patch at Thonock Grove is little more than a Drift-soil.

Brown Boulder Clay is seen to a depth of 5 feet on the west of the long strip of sand west of Corringham, and there is evidence of red Boulder Clay on the east of the same strip; red clay marbled with grey mottling, and containing small fragments of hard chalk and white decomposed flint, occurs by the lane east of Pilham.

The clay is again red with grey veins north of the letters "tall" of the name Dunstall in this and in many of the places above mentioned, resembling that which occurs in the Ancholme Valley (p. 141). The red colour in this instance may be due to the ferruginous character of the *A. semicostatus* zone on which the clay lies. Towards Gawthorpe it is brownish and chalky, with numerous small bits of flint, and about Willoughton Grange, and from Harpswell Lane to the northern margin of the Sheet, it is of a typical greyish-brown, except near the letters "gh" in Willoughton Grange, where it is red mottled with grey, the colour being probably due to an ironstone bed in the Lias, which should occur about here. Lias clay is exposed in the bottom of the valley by Willoughton Grange, but is covered in the slopes by loam and clay, with bits of flint and foreign pebbles or sand.

The eastern limit of the chalky Boulder Clay, south of Willoughton, and again west of Hemswell, is very doubtful; the Middle Lias Rock-bed and the lower part of the Upper Lias are concealed by sandy and loamy soil, which may be either a representative of the Boulder Clay, or talus and rainwash from the Lower Estuarine Beds.

Between Harpswell and Glentworth a patch of sand, possibly talus, obscures the junction of the Rock-bed with the Upper Lias. Near the northern extremity of this patch stiff clay (whether Boulder Clay or Lias could not be ascertained) is exposed in a pit. At a mile south of Hemswell church, the Boulder Clay is red, mottled with grey veins, and resembles the newer clay (? Glacial) of the Ancholme valley (p. 141), so closely that it could readily be believed that there were here two Boulder Clays. But even making the most of the differences in lithological character in this district, it would be impossible to split up this sheet of Boulder Clay with any degree of exactitude.

West of the Trent.

The single occurrence of Boulder Clay on the west of the Trent has been noted by Mr. Dalton. It caps the hill west of Woodhouse Common, extending some distance into the Quarter-Sheet 82, S.E. Its identification as a Glacial clay was of importance as determining the age of the gravel on which it rests; its characters have been described in conjunction with those of the subjacent gravel, p. 128.

THE PURPLE AND HESSLE CLAY TYPE.

On the east side of the Wold a Boulder Clay of an entirely different appearance and origin is found. It overspreads the lower slopes of the Chalk towards the east and underlies the marsh-deposits which fringe the Lincolnshire coast from Grimsby to the fens. This ground has been mapped by Mr. Jukes-Browne, and a full description of the Superficial Deposits has been given by him in the Explanation of Sheet 84, to which the reader is referred. The following observations on the extension of this clay into the present sheet are from the pen of the same observer:—

From the main mass of these clays tongues extend far into the valleys which intersect the hills, and in two cases these pass westwards into Sheet 83. The first case is at Weston, where the valley north-east of the church is occupied by a reddish brown clay overlying gravel. The clay has been dug for brick-making by the road-side two furlongs north-east of the church, and there are several large gravel-pits to the northward, showing coarse flint-gravel overlaid by a few feet of red-brown Hesse clay.

A tongue of similar brown Boulder Clay lies in the valley by Wyham Top House, south of Cadeby, but is not exposed in any recent cuttings.

At the head of the valley south-west of the above, and about a mile east of Lambcroft Walk, there is an isolated patch of similar clay in which a small hole had been dug. This clay here is of a purplish-brown colour and is crowded with small quartz grains; stones and boulders of many kinds are abundant—chalk, flint, schist, quartzite, basalt, and greenstone. The modern watercourse cuts through this outlier. The level of the surface here may be about 250 feet above the sea.

A. J. J. B.

The localities in which Mr. Jukes-Browne has observed a reddish brown type of Boulder Clay occurring at a high level, and apparently above the main mass of Boulder Clay of the neighbourhood of Market Rasen, will now be taken in order. As previously stated, this clay is considered by him to be the same as the brown and buff-coloured clay which borders the Witham fen on the west (p. 133), and both to be correlative with the Hesse series. He describes its occurrence as follows:—

The most southerly locality to the north of the Witham, where similar brown clay has been noticed, is round Swinthorpe and House-on-the-Hill, near Snelland. The high ground here consists of clay which has a uniform reddish-brown colour, covered in places with shallow patches of sand. The clay contains very few stones, and is altogether different from the ordinary blue and grey Boulder Clay of the surrounding slopes. In the railway cutting west of Wickenby I observed the following section in the upper part of the bank:—

	Ft.
Sandy soil - - - -	3
Dark red brown clay mottled in places with grey -	1
Yellow brown sand full of flints - -	1+

Part of Wickenby stands on the brown clay, but east of the village the ridge is capped by some depth of sand only, which rests upon the blue Boulder Clay with chalk pebbles.

Park Farm, north of Snarford, stands upon a ridge of the same red brown clay, which is continued north-eastward to Faldingworth, where it seems to pass into sand and gravel, resting on grey chalky Boulder Clay. Another small patch of brown sand, which may once have been connected with the above, occurs between Faldingworth and Buslingthorpe.

Another large patch of the brown clay occurs on the high ground between Buslingthorpe and Middle Rasen. In this, about a mile-and-a-half S.S.W. of Middle Rasen Church, is an old brickyard, the clay exposed being of a dark red or purple brown colour, with bluish streaks, containing small calcareous concretions (race) and a very few bits of chalk; the clay, however, is singularly free from stones of any kind. Three furlongs south-east of this brickyard, in the ditch by the side of the grass road, I found many pebbles of chalk in clay of the same colour; it is very stiff, tenacious clay. Along the road, half a mile due east of the brickyard, the brown clay appears to rest on loamy sand which lies itself on chalky Boulder Clay of the ordinary type.

At Linwood, about two miles south of Market Rasen, there is another outlying patch of the brown clay, occupying a similar position to the others, namely, along the top of the ridge. At a small pond by the corner of the Wood, two furlongs south-west of the church, I saw about 2 feet of purple brown clay mottled with grey streaks, and containing flints and pebbles of chalk and passing down into yellow sandy loam. This clay is in every respect like that on the east side of the Chalk Wolds.

A. J. J. B.

The reddish-brown and grey clays (? Glacial) of the Ancholme Valley.

These deposits have been mapped by Messrs. Ussher and Jukes-Browne, on the west and east sides respectively of the Ancholme. They are considered by the latter to be of Glacial age, and to belong to the Hessle Series. It will be seen by the map that they occupy the lower slopes of a valley, which appears to have been cut out by denudation in the Oxford Clay, through an overlying sheet of chalky Boulder Clay. On this and other facts, Mr. Jukes-Browne forms an opinion that a considerable interval of time separated the period of chalky Boulder Clay from that of the Hessle Series of East Lincolnshire.*

(a.) *On the west of the Ancholme.*

The following observations on their occurrence in this tract have been made by Mr. Ussher:—

The geology of the low ground bounding the Ancholme Alluvium is very obscure, owing to the very indefinite character of the evidence. There is also considerable difficulty in fixing the points where observations were made, owing to the absence of topographical detail on the map. The red-brown, grey-veined, low-level clay of the Ancholme valley in Sheet 86, is invariably associated with sand and gravel, in which it occurs as an irregular seam, usually from 2 to 4 feet thick, but in that Sheet (86) and also in Sheet 83, there is reason to suppose that the clay has in places thinned out altogether, the deposits then wholly consisting of sand and gravel. This seems to be the case between Bishop's Bridge and Toft; a flattish tract of sand with bits of flint, separates the Ancholme Alluvium from the Oxford Clay, which forms the southern slope of Holme Hill, and a similar sand masks the clay on the top and eastern slope of the hill and passes beneath the Alluvium of the Rase.

* *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 397, and vol. xli., p. 114, and Geology of part of East Lincolnshire (Geological Survey Memoir).

The irregular upward extension of these gravel and sand deposits is also shown to the east of Bishop's Bridge, where they make a small feature, somewhat like a river-terrace, at some height above the Alluvium. Traced northward the deposits pass down the slope and under the Alluvium west of Red House. A ditch section, about 54 chains west of Red House, gave the following section:—

	FEET.
Dark grey alluvial soil - - -	-
Stiff very plastic clay, with much "race," especially in the lower part, apparently devoid of stones, with a slight tendency to reddish mottling, otherwise very like Oxford Clay soil	1½
Pale grey sand and fine gravel - - -	½ +

In this and many other sections it proved a matter of considerable difficulty to distinguish the clay from the Oxford Clay, the only satisfactory proof of its being of later age being the discovery of a bed of sand or gravel beneath it by spudding.

A considerable tract near the mouth of the Glenthams valley is occupied by the gravel, sand, and clay of this series, mantling up the slopes of the higher ground on the borders of the Alluvium. In this valley, at 68 chains in a direction N. 30° E. from Glenthams Church, 1½ feet of brown alluvial loamy clay was found to be underlain by 1 foot of sand with bits of flint, the Oxford Clay being beneath it in this neighbourhood, a very plastic clay mottled with buff. Between a mile and a mile and a half north-east of Glenthams Church, the Alluvium is bounded by flattish tracts of gravel and sand. One mile and 12 chains N. 23° E. from the church, gravel of small fragments of chalk and flint occurs. One mile and 35 chains N. 30° E. from the church, reddish grey-veined clay was spudded into to a depth of 2 feet; in character this clay is identical with the low-lying Ancholme valley clay, and its position disposes of any idea as to the deposit being of alluvial origin. Two miles 7 chains east of Bishops Norton Church, under a dark loamy alluvial soil, yellowish sand was observed, resting upon bluish-grey plastic clay, in which a gravelly seam was noticed; a few yards further north the bluish clay was resting irregularly upon gravel. North of the road from Bishops Norton to the Ancholme, these deposits are chiefly represented by yellowish or brownish sands, with bits of flint, under which the clay is easily visible. In a ditch a few yards north of the road and 10 chains west of the canal, the following succession was obtained:—

Alluvial clay.
 Sand, with bits of flint.
 Red-brown grey-mottled clay.
 Sand.

Near the words Harlam Hill, the ground rises in low mounds formed by a yellowish-brown sand with fragments of flint and with clay. Sand, gravel, and Boulder Clay occur in such close neighbourhood that no clear boundaries can be drawn; the Oxford Clay appears to be at, or near, the surface in some places. West of Harlam Hill the Boulder Clay, which descends to the Alluvium, is probably of the chalky Boulder Clay type, but may be a representative of the low-level clay.

Mention has frequently been made, in describing the Boulder Clay of the Liassic area, of the strong resemblance it bears in places to the Ancholme valley clay. In these instances the resemblance is in colour only; as regards position and contained fragments it is not distinguishable from the chalky Boulder Clay.

W. A. E. U.

(b.) *On the east of the Ancholme.*

In continuing the description of the low-level clays, Mr. Jukes-Browne states:—They appear to set in on the east of the Ancholme, near Red House, north-north-east of Bishops Bridge. They flank the slopes of Oxford Clay at a level which is very little above that of the Alluvium, under which they appear to extend. The clay is sometimes blue mottled with buff, or deep reddish

brown streaked with bluish-grey; the blue clays might at first sight be mistaken for weathered Oxford Clay, were it not that a layer of gravel can generally be found in ditch bottoms underlying both the blue and brown clays. In the clays themselves a stone or pebble is of rare occurrence, and though a flint or pebble of quartzite does now and then occur, no one who inspected the deposits as they appear in the upper part of the Ancholme valley, would regard them as of Glacial age. But when they are followed northward into Sheet 86, they link on to clay beds, which are always of a red brown colour, and which assume the aspect of a Boulder Clay at Brigg and Ferriby.

Round Red House the deposit is chiefly of blue clay, the house itself standing on a patch of sand, which probably overlies the clay, though of this I was not certain.

At and north of the cottage called "The Bottoms" there is sand and gravel, which was seen to a depth of 4 or 5 feet in the ditch by the field road leading eastward. In the deep drain by the new road leading down to the Ancholme, and at a point about half a mile north-west of "The Bottoms," the following section was observed:—

	Ft.
Sandy soil, with pockets of sandy gravel descending into the clay below	2 to 2½
Stiff mottled clay, brown and grey, resting on chalky gravel	2 to 3

It is possible that the chalky gravel here seen below the clay may be the same as that which occupies the surface to the eastward, but as the whole tract is nearly level, the relations of the different clays and gravels are very difficult to make out.

The brickyard, south of Peaseholme, is in the Oxford Clay overlain only by shallow pockets of sand; but the dark brown clays set in again beneath the alluvial soil at Peaseholme.

In the ditch by the field road, running parallel to the north edge of the map, and about two furlongs west of the farmstead called Gulham, a bed of blue silty clay may be seen, overlain and underlain by gravel. In this clay Mr. Ussher and I found a few small pebbles of chalk, and an angular lump of hard quartzite; moreover, tracing it westward, we found it became mottled with brown and red, and, finally, it passed into a red-brown clay, mottled and streaked with grey.

A. J. J. B.

On the south of the cart-road to Peaseholme, between the Ancholme and the canal, the clay was noticed in a ditch under sand and gravel, capped by peaty soil.

W. A. E. U.

The red and grey clays (? Glacial) of the Trent Valley.

From Stow Park Station southwards, for about one and a half miles, a narrow strip of low-lying land, surrounded by slopes of Lias Clay, is over-spread by a red and blue clay. A brickyard, about one mile east of Torksey, shows the following section according to Mr. Cameron:—

	FEET.
Yellow sand	3
Strong red and blue clay	3
Gravelly seam	1
Sandy clay	2
Lias clay	—
	9

The yellow sand thins off a short distance to the north of the kilns, leaving the clay at the surface as shown on the map. This clay, or purplish tenaceous marl, as it was described by Mr. Penning, is stated by Mr. Ussher to resemble the low-lying clay of the Ancholme valley, and is therefore correlated with it on his authority.

A somewhat similar clay has been found by Mr. Cameron, occupying a hollow in the Trent gravel area, one mile north-east of North Searle, and covering an area of three-quarters of a mile in length by about one-quarter in breadth. A brickyard shows the following beds :—

	FEET.
Mottled red and blue clay, with a very few small stones, and particles of "race"	6-8
Yellow sand - - - - -	1½
Blue clay - - - - -	2
Gravel (by information).	

The clay is considered by Mr. Cameron to be of the same age as that described above at Stow Park, to which it appears to correspond in position and character.

CHAPTER XIII.*

POST-GLACIAL DEPOSITS.

ANCIENT GRAVELS (QUARTZITE GRAVELS).

The mapping of these gravels was commenced by Mr. Penning, to whom also the theory, on which their distribution is accounted for, is due. It was unfortunate that ill-health necessitated his retirement from the Geological Survey before he had had time to fully work out the subject. The work commenced by him was taken up in Sheet 70 by Mr. Jukes-Browne, who placed some of the results of his investigations before the Geological Society in 1883.†

The quartzite gravels, which owe their name to the fact of their being principally made up of pebbles of quartzite and other kindred rocks, border the valley of the Trent between Nottingham and Newark, and for some distance northwards. About 2 miles south of the latter town the gravels sweep across the low ground on the east bank of the river, and thence northwards overspread the greater part of the country separating the Trent and the Witham, as far, approximately, as the Foss Dyke, a distance of more than 15 miles. The gravel appears to rest everywhere upon the Lias Clay, which rises through it at intervals in island-like hills of moderate elevation, capped by patches of gravel, similar to that at the lower level. Except for these hills, the gravel forms a plain, sloping down gently from Newark to the north-east at an average rate of 3 feet in the mile. The existing limits of this sheet of gravel appear to have been determined partly by extensive subsequent denudation, as between Skellingthorpe and Boultham, where it has been cut into by numerous small becks. Like all flood-gravels, however, it appears to have been somewhat irregularly distributed originally.

In the Lincoln gorge these quartzite gravels are temporarily lost sight of, but they reappear in the low ground bordering the Witham valley on the east side of the Oolite hills, and extend along this valley beyond the margin of this Sheet, the quartzite pebbles becoming gradually less abundant southwards, though still forming the mass of the deposit as far as Bardney, 11 miles from Lincoln. On the east side, they are finally replaced by flints in the neighbourhood of Kirkstead, where the Witham valley gravels merge into those of the Bain valley, as hereafter described.

In determining the age and origin of these gravels, it should be first noted that throughout the large area they occupy there is no instance of Boulder Clay occurring either over or in them. They are seen, on the contrary, in more than one section, to rest on an eroded surface of the Boulder Clay, which overspreads the

* Written, except where otherwise noted, by Mr. A. Strahan.

† *Quart. Journ. Geol. Soc.*, vol. xxxix., p. 606.

Oxford Clay area. There is, moreover, reason to believe that the cutting up of this sheet of Boulder Clay into the existing gentle hills and valleys had made some progress before the gravels were laid down, inasmuch as the gravels are found partly in the form of patches on the tops of the minor Boulder Clay watersheds, but often overspreading the gentle slopes and descending into some of the shallow valleys. The inference that they are post-Glacial is strengthened by the fact that the quartzite pebbles of which they are so largely composed are almost entirely absent from the Boulder Clay of this district. It has been shown that the materials of which the Boulder Clay is composed have been transported in a southerly direction; those of the gravels, on the other hand, have clearly come from the west, travelling from Newark to Lincoln in a north-easterly direction, and from Lincoln eastwards, and subsequently south-eastwards along the Witham valley.

While so clearly distinct from the Glacial Deposits, the gravels are found, as before stated, to pass into those terraces which border the Trent above Newark in such a manner as to leave no doubt as to their fluvial origin. It was this fact that first suggested to Mr. Penning the theory that is now put forward as being alone capable of accounting for all the observed facts, namely, that these gravels were distributed by an ancient river Trent, which must have at some early post-Glacial period have flowed from Newark to Lincoln, and thence down the present Witham valley, in place of running northwards, as the Trent does now, to join the Humber.

In describing the present course of the Trent, Mr. Jukes-Browne says,* that it flows "in a north-easterly direction through a well-marked valley as far as Newark. Here, however, the river bends to the northward, keeping to the west side of the low Rhætic escarpment, as if it had not been able to cross that comparatively slight obstruction. This northerly course it maintains till it reaches the estuary of the Humber. Now the course of the Trent as far as Newark favours the supposition† that it was determined by the westerly slope of a plane of marine denudation across the edges of the Lower Jurassic strata; but if so, and if it had ever flowed over a surface of Oolitic rocks, why did it not continue this course, so as to run in a transverse valley through the Oolitic escarpment and into the Wash instead of into the Humber?" He then proceeds to show that the Lincoln gorge occupies a position, and is of a size, that would be satisfactorily accounted for by the passage of such a river as the Trent.

It has been elsewhere‡ shown that there is good evidence of a similar character that the courses of the Witham and the Devon have also undergone changes. At Ancaster the Oolite escarpment is breached as at Lincoln; the old gravels connected with the Witham above lead directly to this breach, and through it to

* *Quart. Journ. Geol. Soc.*, vol. xxxix., p. 606.

† Ramsay, "Physical Geography and Geology of Great Britain." 5th Ed., p. 518.

‡ Geological Survey Memoir on Sheet 70.

Sleaford. Other gravels connected with the upper course of the Devon stretch over the Lias for many miles at the foot of the Oolite escarpment in a manner that leads Mr. Jukes-Browne* to believe that the ancient Devon ran northward to join the Trent, nearly along the present course of the Brant. The modern Devon diverges from the line of its ancient gravels to join the Trent at Newark, and the modern Witham, passing by the gorge at Ancaster and crossing the ancient gravels of the Devon, enters the area of the ancient Trent gravels, and traverses the Oolite escarpment at Lincoln. The evidence for such changes having taken place is strengthened by its repetition in the three cases above alluded to. It is difficult to account for the same peculiarities in the distribution of these gravels being repeated in these rivers on any other supposition than that of their having undergone a similar divergence from their old channels.

In the case of the Trent gravels, a noticeable point is the prevalence of quartzite pebbles. All the gravels bordering the Trent above Dunham are largely made up of these pebbles, the only exception being the low cliff at Clifton Harbour, where a gravel of Keuper Marl débris is exposed, as hereafter noted (p. 163). It was the existence of these quartzites that made the identification of the ancient gravels on the east with those on the west of the Oolite escarpment possible, and thus afforded indisputable proof that the former had been brought to their present position by way of the Lincoln gorge. The pebbles have been doubtless derived from the Bunter Pebble Beds, which run north and south in a broad belt, about 20-25 miles west of Lincoln, and are traversed by the Trent near Nottingham, about 17 miles above Newark. The distance from the nearest exposure of the Pebble Beds to Kirkstead, where the quartzite gravel merges into flint-gravel, measured along such a course as the Trent is supposed to have taken, amounts to 50 miles. It appears probable, however, that much of the ground on the east of the Pebble Bed outcrop has been formerly overspread by a quartzite gravel derived from the same source, but of Glacial age. Patches of such gravel are found at several points in the Keuper Marl area, as at Woodhouse Common, (p. 128), near Grove, (p. 129), and near Gringley, and, as previously explained, probably are relics of a once more extensive sheet. It is also possible that some of those patches which cap the Lias hills within the area of the Trent gravels are also of Glacial age, though from the difficulty of separating deposits lithologically so similar, it has been decided to class them provisionally with the ancient river gravels. It may, therefore, be supposed that the Trent quartzite gravels are principally made up of the waste of Glacial Beds, and that the pebbles have been transported by the river a small portion only of the total distance from their original source.

The levels of the ground separating the Trent from the Witham show that a very trifling alteration would serve to effect such a

* *Quart. Journ. Geol. Soc.*, vol. xxxix., p. 607.

change as has been supposed to have taken place. On more than one occasion the waters of the Trent in time of flood have found their way to Lincoln. In November 1770, the Foss Dyke at Torksey gave way, and the water came to Lincoln, flooding the villages of Saxelby, Torksey, Brampton, Fenton, Kettlethorpe, Thorney, Skellingthorpe and Boultham. In 1795* the bank of the Trent broke at Spaldford, and the flood was only prevented from passing freely through the Lincoln gorge by the fact of the High Street in Lincoln being artificially raised (probably by the Romans) from 12 to 15 feet above the surrounding land. The levels taken by the Ordnance Survey show that the level of the Lincoln and Torksey road varies from 17 to $20\frac{1}{2}$ feet above Ordnance Datum, the bed of the Till at Hathow Bridge being only $11\frac{1}{2}$ feet above this Datum. The floods referred to above seem to have passed round the north side of Doddington, and along the course of the Foss Dyke. None are known to have passed by the gap at Eagle and along the Thorpe and Boultham valley.

The mapping of the area occupied by these gravels west of Lincoln was commenced by Mr. Penning and completed by Mr. Cameron. One of the best sections noted by the latter is on the Midland Railway, one mile north-east of Hykeham Station, in a pit excavated originally for ballast, but now used as a reservoir by the Lincoln Waterworks Company. The gravel is exposed to a depth of 7 feet, and is packed with well-rounded pebbles of quartzite, hornstone, &c., flints being comparatively rare and not much rolled; a few Carboniferous rocks and others also occur. The total thickness of the gravel according to Mr. Teague, engineer to the waterworks, is 17 feet. A little further to the east is a second excavation, made during the construction of the Lincoln and Spalding Railway. Mr. Penning notes that at the south end there occur 4 feet of light coloured sand, stained in places with oxide of iron; at the north end is dug, to a depth of 6 feet, gravel composed of small rolled pebbles of quartz and quartzite, a few flints, and some Oolitic débris, much less waterworn; in the middle of the gravel is a bed of iron-stained sand 9 inches thick.

About Swallow Beck and Greg Hall there are shallow pits in the same deposit. One mile south-east of Skellingthorpe he observed 5 feet of quartzite gravel with patches of ferruginous sand, and three quarters of a mile north-east of Doddington a similar deposit dug to a depth of 4 feet. An old sand-pit south-east of Saxelby Gibbet shows 4 feet of fine brown laminated sand.

As previously noted, the sinuous outline of the gravel area between Boultham and Skellingthorpe is the result of the erosive action of the small becks draining into the Witham and Till. It seems likely that before these rivers assumed their present channels the gravel must have extended further to the north and east, and probably through the Lincoln gorge. There is, however, only one instance in all the sections in the gorge which are quoted in the Appendix, of any mention of quartzite gravel, namely, in the section at Canwick. Mr. Penning here observed 8 feet of the gravel beneath $19\frac{1}{2}$ feet of sand silt and sandy clay. This may be a relic of the Trent gravel that has escaped erosion, or more probably is a gravel made up by the Witham from the old Trent Gravels.

* "Fens and Floods of Mid-Lincolnshire," by J. S. Padley, County Surveyor of Roads and Bridges, Lincoln, 1881 (plan), (*see* p. 174).

Soon after leaving the east end of the gorge, however, the gravels reappear, occupying a similar position with regard to the recent Alluvium as on the west side of Lincoln. The Witham valley is here a broad but shallow excavation in the Boulder Clay, and the gravel occurs on the tops of the low Boulder Clay hills in patches, which are clearly remnants of a once continuous sheet. The base of the gravel is at first some 20 feet above the fen-level, but descends southwards so as to finally touch the Alluvium. It will be convenient to describe first the west side of the fen, where the gravel has been mapped by Messrs. Penning and Jukes-Browne. The following observations on the northern part of this area are from the note-book of Mr. Penning.

In a pit one mile east-south-east of Heighington there may be seen 6 feet of sandy gravel with patches of sand, the whole being very ferruginous.

The pebbles are small and round, nearly all being quartzite, but there are also some flints and ironstone fragments.

Three-quarters of a mile north-east of Heighington is a pit showing 5 feet of quartzite pebble gravel, with a few angular flints.

One mile north of Potter Hanworth, a gravel-pit exposes the following section :—

	Fr.
Soil and rainwash - - - -	2
Quartzite gravel with some flints, and sand - -	5½
Clay (presumed from the fact of water standing in the pit).	

Two gravel-pits, about one mile north-east of Nocton, show sandy current-bedded gravel with patches of sand. The deposit is very ferruginous, the pebbles nearly all quartzite and very small. About 6 feet of gravel are seen.

In the gravel-pits about 1 mile east of Nocton the following section was seen :—

	Fr.
Fine quartzite gravel and sand - - -	3-4
Dark-brown sand, contorted - - -	2
Gravel as above, nearly all quartzite with a few flints not rounded - - -	6
Dark-grey Boulder Clay.	

In the valley running eastwards to the Witham from Dunston there is a low-level gravel of more recent alluvial origin. Consisting, as it does, entirely of débris washed down from the slopes of the Oolitic hills to the west, it contrasts strongly with the older and more widely spread quartzite gravels described above.

The description of the quartzite gravels of this area is continued by Mr. Jukes-Browne as follows :—

South of Nocton Wood the series is interrupted by the valley of a stream draining from the west; but the high ground traversed by the road from Metheringham is capped by sand and gravel of similar character.

Near the southern extremity of this outlier is a small pit whence gravel has been extracted; small rounded pebbles of quartz and quartzite are the chief constituents, but pebbles of sandstone, black hornstone with quartz veins, and a few flints also occur.

Crossing the next valley we reach a more extensive plateau of the quartzite gravel, deeply furrowed on its northern and eastern sides by the runlets which flow from the springs thrown out along its margin; these cut down to the Boulder Clay, and the surface of the country is thus diversified by a system of small subsidiary valleys all draining on to the alluvial level of the Witham.

The north end of the plateau is nearly severed from the main mass by one of these watercourses; it has indeed been mapped as an outlier, for though there is a connecting ridge by Blankney Wood, the Boulder Clay seems here to reach the surface. There is no great depth of gravel anywhere in the neighbourhood of this wood, but westward towards Blankney Moor a thicker deposit of sand occupies the ground. This extends southward over Linwood Moor, its depths averaging from 8 to 10 feet. A good supply of water is always to be found at its base.

The village of Martin stands on a long spur left by the process of valley erosion above mentioned, and the material forming this spur appears to be chiefly gravel; it is exposed in a pit about a quarter of a mile north-west of the church, 6 feet of pebbly gravel with lenticular layers of sand being here seen; the bedding is irregular, and is in places contorted; the usual quartzite pebbles occur, and there are a few flints.

Most of Timberland stands on Boulder Clay, but a ridge of the gravel extends into the north end of the village, and there is a large gravel-pit half a mile north-west of the church; there were no recent excavations here in 1878, but I was told that below the gravel there is a bed of clean sand. The following pebbles were noticed: pink, purple, and brown quartzite, white and pink quartz, brecciated quartz, black hornstone (some with veins of quartz), hard grit or sandstone, porphyritic granite (two pebbles), and some few flints, but the last-named were all broken and angular, thus presenting a striking contrast to the rest, which were all rounded water-worn pebbles that had evidently travelled a long distance.

Another pit half a mile west-south-west of the church exposes a section of similar gravel with sand below, and the plateau passes southward into Sheet 70 by Tilney, Thorpe, and Walcott. For particulars regarding its further extension the reader is referred to the Memoir on that Map.

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Crossing now to the east side of the fen, we find the gravels first appearing at Bardney. The map, which was in this part constructed by Mr. Cameron, shows a patch of considerable extent occupying the higher and flatter portion of the hill on which the village stands, and sweeping thence on to the lower ground on the north and east sides. It is therefore clear that the gravel rests on an undulating surface of Boulder Clay. In other words, lines of drainage had been established, and a certain amount of erosion of the Boulder Clay plain had been effected, before the deposition of the gravels.

On the top of the hill at Bardney there is seen little more than a sandy soil with quartzite pebbles, though Mr. Cameron was informed that gravel was found to extend to a depth of 8 feet in a well. But on Bardney Common, on the north-east side of the hill, there are a gravel-pit and a brickyard close together, affording good sections. The gravel-pit shows the following section:—

	Fr.
Pale bluish-grey gritty clay with stones	- - 3-4
Stratified quartzite gravel, exposed to 3 feet and said to be	- - 10

The stones in the gritty clay are chiefly flint in small fragments, with a few pieces of chalk and some quartzite pebbles. It rests with an extremely indefinite and irregular base in hollows and pipes in the underlying gravel, and appears to be an alluvial wash, such as is frequently deposited by flood-waters over a gravel-flat.* The gravel is stratified, and made up principally of quartzite pebbles and subangular fragments of flint. Mr. Cameron

* This view of its origin is not shared by Mr. Camerou, who believes this clay to be a true Boulder Clay, a conclusion which would make the quartzite gravels of this locality of Glacial age.

observed also a fragment of granite and of some other foreign rocks. Rolled shells of *Gryphæa incurva* from the Liassic area also occur.

In the brick-pit the section is as follows :—

	Ft.
Stratified quartzite gravel - - - -	9-10
Strong blue Boulder Clay - - - -	2-3
Kimeridge clay.	

The whole thickness of the gravel is well seen here. It is well stratified and full of quartzite pebbles and fragments of flint, with very little sand. It rests with a sharply defined base on a nearly level well-washed floor of Boulder Clay, a tough blue clay with a few foreign boulders of chalk, basalt, Oolite, and Carboniferous Limestone and white sandstone, but without any quartzite pebbles.

The abundance of quartzite pebbles in the gravel, and their total absence in the Boulder Clay, taken in connexion with the marked signs of unconformity between these deposits, make the evidence of their belonging to different periods very strong as observable in this pit alone.

The patches at Southrey and south of Tupholme appear to be thin coatings of gravel of a similar nature overspreading the higher parts and sometimes also the flanks of the gentle undulations of the Boulder Clay.

Again, on the Horsington ridge and at a mile distant to the north-west on lower ground, there are two patches, probably belonging to this series. The sandy soil, from which alone their presence is inferred, occurs in a ground overspread by stiff bluish Boulder Clay, not of the intensely chalky type, and not therefore likely to yield a sandy soil on weathering as has happened at Thimbleby (*see postea*, p. 155).

South of Bardney the quartzite pebbles, though still abundant, do not occur in such profusion, and finally disappear about Tattershall Thorpe, where the Witham Valley deposits merge into those of the Bain. Similarly, they become less abundant in the parts further removed from the present Witham valley. Their distribution thus affords a strong confirmation of the theory that their source lay to the west of the Lincoln gorge, and that they travelled thence by way of the Witham valley.

In continuing the description of the ground further to the south, Mr. Jukes-Browne writes :—

It is evident that this gravel once extended to the south-east, as a continuous belt or terrace flanking the Witham Valley; but its continuity is now interrupted by the valleys of several little brooks or becks, which drain the country to the north-east and have trenched through this gravel belt, and have broken it up into a series of detached patches.

Thus, between the two little streams coming respectively from Tupholme Abbey and from Campney, there is a small patch of gravel and sand, the former composed chiefly of red flints with many quartz and quartzite pebbles, as may be seen in the pond near the farmstead three-quarters of a mile north-east of Southrey Station. The low ridge intervening between Campney and Bucknall becks is also capped by similar material. This patch is nearly a mile in length, and its base line gradually slopes fenwards, finally passing under the alluvial beds which bound its southern extremity. Near the farm here there is a gravel-pit 7 feet deep in fine sandy gravel. The larger number of the stones are rounded pebbles of brownish quartzite, the remainder being chiefly rounded quartz pebbles with small broken and angular flints, which do not appear to have travelled so far as the quartz and quartzite. The stones are remarkably even in size, but at one end of the pit an interstratified layer of fine yellow sand occurred. I was informed that the total depth of gravel

here was 9 feet, and that the subjacent bed was a dark blue clay with chalk stones.

The next patch of gravel extends from the Witham bank, near Hare Booth, to a point just south of Lady's Hole Bridge, and there is a smaller outlier to the east of this place.

There are old gravel-pits a third of a mile north-east of Hare Booth, where the depth of gravel is said to have been 7 feet, with clean white sand below. A small recent excavation shows that the pebbles consist of brownish quartzite, pink and white quartz, black hornstone, and flint fragments.

East of Stixwould Ferry there is a larger spread of gravel and sand, covering an area of more than a square mile. There are no excavations of any depth in this neighbourhood, but similar material to that already described has been obtained from a small pit near Mr. Gaunt's Farm, about a mile south-east of the Ferry, and there is a small sand-pit half a mile south-south-east of Stixwould Church.

The base of the gravel rises to the north-east, and the village of Stixwould stands upon an outlier at a greater elevation than that of the area just described.

Eastward there is a long and narrow strip of sand commencing near the corner of Hawstead Wood, and stretching southward for nearly a mile by the house called Edlington Moor Farm. Walking down the road which leads from this farm towards Woodhall Spa, Boulder Clay may be seen where the drain runs under the road; but south of this point we gain a sandy soil, and a deserted brickyard on the east side of the road exhibits the following section, when it is not too full of water:—

Yellow sand and loam, with a few pebbles	-	-	6 to 8 feet.
Dark blue clay below, with septaria	-	-	—

About Woodhall Spa small excavations show the soil to be a pebbly sand, pebbles of quartz and quartzite, and fragments of reddish flint occurring in nearly equal numbers, but rarely in such quantity as to give the aspect of gravel to the deposit, though when sifted the material is used for mending roads and paths.

I was informed by Mr. R. Cuffe, of the Villa, Woodhall Spa, that an excavation had been made in his garden to a depth of about 12 feet, the sand at the bottom being full of water; northward the deposit thins out against Boulder Clay, which comes to the surface in the wood by the Spa Bath House; southward the depth of sandy material appears to increase, for the well at the school-house near the church is said to be 18 feet deep with gravel at the bottom.

The gravel-terrace, which we have followed along the east bank of the Witham Valley, now becomes merged into a widespread expanse of sand and gravel, which stretches eastward over Woodhall and Kirkby Moors, and southward through the Kirkstead and Tattershall Park estates. An interesting fact, and one that throws much light on the origin of the deposit, may also be noted, viz., that the Witham Valley gravel gradually loses its distinctive characters as it merges into this wider area; the proportion of quartz and quartzite pebbles becomes less and less, while the number and size of the flints increase as we pass to the south-east until near Tattershall Thorpe hardly any other stones than flints are to be found in the gravelly layers of the deposit or on the surface of the fields.

In describing the district occupied by this extensive formation of sand and gravel, it will be convenient to take Woodhall Spa as a starting point, and indicate the sections visible in proceeding southward, eastward, and northward from that place.

Along the road to Kirkstead Ferry and Station, and by the side of the railway, gravel and sand are visible occasionally, till they finally pass below

the peat and Alluvium of the fen. About Kirkstead, pebbles of quartz and quartzite are still common in the gravelly layers.

Much gravel has been dug out of the fields near Kirkstead Church, but no pits were open during our stay in the neighbourhood; the following, therefore, is taken from the Memoir by Mr. Skerthly, who had the opportunity of visiting this spot in 1872:—*

"A very good section is seen on the Church Farm, 15 chains S.S.E. from Kirkstead Church. Under about 6 inches of soil, gravel from 0 to 3 feet in thickness lies upon an eroded surface of Boulder Clay which is seen to a depth of 12 feet. The gravel is sandy, unstratified, and nearly everywhere stained and cemented with oxide of iron close to the surface. It lies irregularly, filling up hollows in the eroded surface of the clay, and is sometimes altogether wanting. The clay is not worked up into the gravel as happens in some places. At the farmhouse, a little S.W. of the above, is a well about 12 feet deep, dug entirely in gravel. This house is only slightly higher than the level of the land at the above pit. Similar pits have been opened elsewhere on this farm, and the gravel is found to lie very irregularly, varying from 1 to 20 feet in thickness."

By the road to Tattershall (at the point where a little stream crosses it), 1 mile south-east of Kirkstead Church, there are some shallow pits where the following section is shown:—

Sandy soil	-	-	-	-	-	1 foot.
"Pan" of conglomerate or hardened sand cemented by oxide of iron	-	-	-	-	-	3 to 6 inches.
Sandy gravel	-	-	-	-	-	2 to 3 feet.
Dark-coloured Boulder Clay	-	-	-	-	-	2 feet seen.

The depth of sand, &c. near the road is nearly 5 feet, but eastward the clay comes nearer the surface, and the gravel lies in pockets only 2 or 3 feet deep. It is chiefly composed of small broken flints, coloured red and brown, with some few rounded pebbles of quartzite.

At the pond south of Tattershall Lodge similar beds are seen, 3 or 4 feet deep, resting on the Boulder Clay.

The hard ferruginous layer is of common occurrence all over this district, and will be mentioned again in the sequel.

Starting again from Woodhall Spa, along the Tattershall Road, some old pits will be noticed on the east side of the road about a quarter of a mile south of the church. The gravel here is not more than 4 or 5 feet deep, with Boulder Clay below which comes to the surface toward the north-east.

All the Tattershall Park Estate lying to the north-east of the Tattershall Road was formerly a dense wood, but the greater part of this has now been cut down, and much of it has recently been brought under the plough. The soil is everywhere extremely poor and barren, being composed of white or yellow sand, and it has been found necessary "to clay" the whole surface before attempting to grow crops of any strength. The underlying Boulder Clay has been used for this purpose, and excavations have been made through the sand here and there in order to reach it.

One of these is near the barn about three-quarters of a mile east of the Abbey Inn. Here 3 or 4 feet of stony sand, with gravelly layers, are shown, resting very irregularly on the eroded surface of the Boulder Clay. The stones are chiefly flints, but quartzite pebbles are common.

Another pit about half a mile south-south-east of the above exhibits sand and loam, with little or no gravel, resting on Boulder Clay in a similar manner. The section at one end was noted as follows:—

						ft.
Black vegetable soil, underlaid by a seam of clean white sand	-	-	-	-	-	1
Soft brown sand and sandy loam	-	-	-	-	-	2 to 3
Dark Boulder Clay	-	-	-	-	-	4 to 5+

* Geology of the Fenland (Memoirs of the Geological Survey), p. 197.

At the farmstead south-east of this pit, and 1 mile north-north-west of Tattershall Thorpe, the depth of sand is 6 feet. The deep ditch by the roadside south of this farm gives the following exposure:—

					Ft.
Black sandy soil	-	-	-	-	1
Hard pan of compacted brown sand	-	-	-	-	0½
Sandy <i>flint</i> gravel	-	-	-	-	4

Pipes filled with black and brown sand pass from the top soil through the beds below. The little stream to the south has cut its channel down to the Boulder Clay. At the farm belonging to Mr. Joseph Patchett, north of Tattershall Thorpe, the well is said to be 14 feet deep, passing through sand and gravel without touching the clay.

Half a mile north of this farm, and the same distance south-west of that named Park House on the map, is a large clay-pit where pockets of sandy gravel are seen, and the upper part of the clay below them is worked up into a kind of brownish loam. To the north-east of this point the Boulder Clay rises to the surface and forms a clay soil, but the south end of Kirkby Moor is covered by a considerable depth of sand.

Returning again to Woodhall Spa, and proceeding eastwards, a pit will be found in the field half a mile east of the church, exposing the following beds:—

					Ft.
Sandy soil and yellow sand	-	-	-	-	3
Layer of fine gravel	-	-	-	-	0½
Boulder Clay	-	-	-	-	4

Southward, the Boulder Clay comes to the surface along the flank of the valley formed by the little beck that runs down to Kirkstead. Half a mile east of the pit above mentioned clean yellow and white sands have been dug by the side of the road leading to Kirkby-super-Bain. Where the beck crosses this road the sand is thin, and clay has been dug from the neighbouring fields, but eastward over Kirkby Moor the depth of sand increases considerably. Near the keeper's lodge are some shallow pits which show the usual layer of hardened sand, cemented by oxide of iron, underlying the blackish sandy soil; below about 4 feet of yellow sand are seen. The well at the cottage is said to be 15 feet deep in the same sand, and there is generally a plentiful supply of water. The hard ferruginous layer below the soil is locally called "ozzen" or "uzzen," and I was informed that in planting trees it was found necessary to dig through and break up this layer, as the roots could not penetrate it.

This thick deposit of sand forms a barren district upon which little grows naturally except dwarf oaks, silver birch, braken and heather, and in which the clay lies so deep that it is difficult and expensive to render it fit for cultivation. The surface is uneven and undulating, and the sand finally thins out against the ridge of Boulder Clay which forms the slope overlooking the valley of the Bain.

Its thin edge may be seen in some pits near the farm one mile north-west of Kirkby, clay having been dug here under 3 or 4 feet of sand.

Returning once more to Woodhall Spa we will note the lie and position of the sands to the north and north-east of that place. The ground between the Victoria Hotel and the Lodge at Wood Corner is occupied by Boulder Clay, which underlies also the greater part of Braken Wood, but the sand extends all round the eastern and northern borders of this wood.

Near the *W* of the words "Wood Corner" is an extensive pit, once dug for sand and gravel but now overgrown. The depth to which these materials extended is said to have been 10 or 12 feet.

White and yellow sands may be seen in the pits and ditches on the north side of the wood, and there is a small gravel-pit south of the point where the roads meet at Reedbeck. The bottom of this is in brown sand, false-bedded, with layers of pebbles, mostly consisting of quartzites and hornstones mixed with some flints. This is surmounted by a layer or "pan" of hard ferruginous sand (*uzzen*), more irregular than usual and at a greater depth from the surface (*viz.*, 2 to 3 feet). The gravel and gravelly soil above is also hardened into masses by the infiltration of oxide of iron.

The depth of gravel and sand near the blacksmith's is from 6 to 8 feet, but eastward it appears to thicken, and at the farmstead near the intersection of road and railway the depth of the well is said to be more than 40 feet. The well-sinker states that he dug through clean sand for 12 yards, passing then into gravel and shingle, and finding water at a depth of 14 yards (42 feet) without touching the clay.

A small pit in the field between Sandy Lane and Woodside shows yellow sand, containing scattered flints and a few quartzite pebbles, the latter being in the minority here, while at Reedbeck they formed the majority.

Between the Horncastle Road and the village of Roughton the surface of the Boulder Clay underlying the sand appears to be very uneven, so that several knobs and ridges of the clay have been bared by subsequent denudation. One of these, close to Roughton, seems to be unusually steep-sided, for Boulder Clay is seen in a pond three-eighths of a mile west of the church, while at the cottages about 100 yards east of this spot the well was sunk 20 feet deep in sand reaching quicksand and water without touching the clay. Here, therefore, we have evidence of deep channels and the scoring power of currents. We may look upon the extensive out-spread of sand and gravel over the area just described as having been accumulated in the angle between the meeting-point of the Bain and the Trent, at a time when the latter followed the present valley of the Witham.

On the eastern side of the Bain valley there are several disconnected patches of gravel and sand at a similar high level above the Alluvium level. Two occur between Haltham and Scrivelsby, a third underlies the greater part of Haltham Wood, and a still larger and longer one runs southward by Toft Hill to Fulsby. Where gravel is found it is almost entirely composed of flints. There are two small patches of sand at Wood Enderby and another north of Wilksby, while south-west of Wilksby there is a larger patch of gravel and sand on either side of the road. Gravel has been dug at the south end of the village, where it overlies sand, the two together being about 8 feet deep; but on the east side of the road there are only 2 or 3 feet of sand, so that the surface on which the sand and gravel rest must be very irregular.

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On the west side of the Bain a similar series of patches of gravelly soil caps the Boulder Clay watersheds. Four patches occur, namely, at Martin, Thornton, Langton, and Thimbleby. In each case the gravel extends a short distance westwards, along the tops of the low hills separating the becks which flow westwards to the Witham. The gravel, so far as can be seen in the absence of any pits, consists of a loose unstratified sand more or less packed with flints. It is such a deposit as would result from the weathering of the intensely chalky Boulder Clay on which it rests; in fact, much of the level ground on the tops of the hills further to the north is overspread by a thin soil of a similar character. These patches may be considered to represent portions of the original surface of the Boulder Clay that have been exposed to subaerial action for a long period, but under circumstances which have not been favourable for the removal of the products of decomposition. The sides and bottoms of the valleys separating these patches, down which there is a sufficient slope for water to exert transporting power, consist of clean white Boulder Clay.

The patch indicated on the map at The Lodge, east of Thornton, is of a different character. The sand and gravel here form a small knoll in the valley of the Bain, rising considerably higher than the river-terraces which border the modern Alluvium along this part of the river, and are doubtless of later age. A small pit shows fine current-bedded sand with a few bands of angular flints. The deposit appears to belong to the same series which overspreads Kirkstead. From the nature of the case, however, it is difficult to

separate outliers of these ancient gravels from such deposits as occur at Thimbleby and Langton; to these latter the name "denudation gravels"* may be conveniently applied.

Patches of gravel, probably in part of a similar origin, have been observed by Mr. Cameron in the neighbourhood of Wragby. At Lower Langton, about 2 miles south-east of Wragby, there are several old shallow gravel-pits, and one now in use, in which Mr. Cameron noted the following section:—

	Fr.
Sand, with a few flints	3
Sandy clay, yellowish, with a few flints	1-2
Sand and gravel	6

In the sand and gravel the greater part of the stones (70-80 per cent.) were flints; sandstones and a few quartzites also occurred.

On the west and north-east sides of Wragby the nature of the soil seems to indicate the occurrence of similar deposits, and between Snelland and Holton gravel has been excavated to a small depth. In the patch running north from Stainton towards Snelland there are but few sections. The railway-cutting at the former place shows a light gravelly soil resting on the usual stiff Boulder Clay of the district. At the north end of the cutting flint-gravel has been dug, apparently from a gravelly pocket in the Boulder Clay. One-third of a mile west-south-west of Snelland Station there are old gravel-pits by the side of the road. There appear to be 5-6 feet of flint-gravel resting on Boulder Clay.

* This term was first used by Mr. Searles Wood in description of similar deposits.

CHAPTER XIV.*

POST-GLACIAL DEPOSITS—*continued.*

OLD BLOWN SAND.

One of the most extensive of the superficial Deposits is that to which the name of the Moor Sand has been applied in consequence of its forming the heathy tracts, known in the neighbourhood of Market Rasen and Caistor as Moors. Usselby Moor, and in Sheet 86, Holton-le-Moor, Nettleton Moor, Caistor Moor, and Clixby Moor, may be cited as examples of the districts where the deposit attains its greatest development. Kirkby Moor and Mareham Moor in the south are also on a deposit which appears to be in part of the same age and origin. From its nature and distribution it is clearly of æolian origin. It is everywhere a very fine-grained white or iron-stained sand without stones, of very variable thickness. Towards the margins of the main mass it generally follows lines of valley, as about Market Rasen, Barkwith, and Panton, but frequently it mounts the gentle Boulder Clay slopes and occurs in thin patches on the level tops of the undulations. While clearly unconformable to the Boulder Clay, inasmuch as it follows valleys cut in post-Glacial times in this deposit, it cannot be regarded as a recent deposit. Except in the case of newly ploughed fields it has now ceased to move. It has, moreover, been subjected to considerable denudation, some of the valleys appearing to have been in part formed or deepened since its distribution. It seems clear that it had its origin in the alluvial flats of the Ancholme in the north, and of the Witham in the south. Before the erection of banks and sluices, the broad alluvial flats of these rivers were liable to be overflowed by the tide, and formed salt marshes on which vegetation was scanty. In dry weather such marshes would yield to the wind a fine dusty sand, as may be seen to be the case at the present time in other parts of the country. The tide having been banked out, the marshes are now under cultivation, and the supply of sand is almost entirely stopped.

The areas occupied by the sand clearly show its connexion with the above-mentioned rivers. The great spread of Caistor and Market Rasen, with the numerous outlying patches to the south, are in the track of westerly winds blowing over the Ancholme valley. About Horncastle, Wispington, and Minting there is a tract entirely devoid of it, but between Woodhall, Kirkby, and Roughton it is found again on what would be the leeward side of the Witham under the prevalence of westerly winds.

The following extract from the diary of Abraham de la Pryme, 1695, is of interest, as showing the extent to which the sand was moving in a district far removed from its source, at a comparatively recent date. He says:—

“I have been at Caistor again yesterday on some business, and from thence I went to Nettleton, a little mile, to see something there that I thought

* Written, except where otherwise noted, by Mr. A. Strahan.

memorable. All along the Hill side there, for at least a mile, lies a long bed of sand, which has sprung somewhere thereabouts out of the ground, and increas'd to the aforesaid bigness, having covered a great quantity of good ground, and by that means entomb'd several poor people. Within these 20 years it began to move towards this town, and all that part of it that lay close to the hill edge (wh^{ch} was about 25 houses, with their fields and garths) has been destroyed by it these several years, only there is one house, which is a poor man's, that stood it out by his great pains and labour; but as for his folds and gardens they are all covered. It had destroy'd a great deal more of this town, but that, betwixt it and the aforesaid houses that were destroy'd, there runs a strong water spring, or brook, which it cannot get over, neither can it fill it, for as soon as any great rain falls, either in summer or winter upon the hills, it descends thro' this brook soon washes it to its old channel again, &c. So that this quicksand not being able to get over, it goes all along by its side and the side of the hill, and last year broke a great hedge down and has begun to enter into a piece of excellent ground which it will most certainly destroy, and this was the memorable thing that I went to see."

One of the best exposures of the sand was afforded in a pit on Linwood Warren about two miles south-east of Market Rasen; the sand was 10 feet thick, and contained about $1\frac{1}{2}$ feet from the top an ashy grey layer which appeared to be an old soil, the remainder being pale-yellow. It would appear that a temporary cessation had taken place in the accumulation of the sand, leading to a growth of vegetation, which afterwards was buried under $1\frac{1}{2}$ feet of more sand.

The sand here rests on the Kimeridge Clay, which has been exposed also along the course of the stream on the north side of the Warren by erosion. The thickness of the sand here is unusual; about Legsby, North Wood, and Willingham it varies from 1 to 4 feet. As a rule in this neighbourhood it lies in the valleys, but it frequently also mounts the low hills. South of Market Rasen, for example, it thins off gradually on the slope of the hill in which the railway cutting is made, but further to the west runs up on to the highest and flatter portions of the ridge, leaving the slope of Boulder Clay and Oxford Clay bare. The more level ground forming the bottom of the broad valley about Middle Rasen is overspread by a deposit similar in appearance, but which may in part have been washed down from the upper reaches of the streams.

In all the brick-pits round Market Rasen there may be seen from 5 to 6 feet of this sand resting on the Kimeridge Clay, and in the railway cuttings in the same neighbourhood from 4 to 6 feet of sand are seen resting on clay. The sand is in part brightly coloured, orange and buff, and cemented into a friable stone by iron. Near Moor Farm at the northern margin of the sheet I noticed that the sand was travelling under the influence of a high east wind; some deep ditches had been completely filled up, and the undergrowth in the plantation by the roadside half buried within a few days. In the field on the east side of this plantation is an old clay-pit, showing sand with angular flint-fragments arranged along the highly inclined current-bedding planes. The sand was about 8 feet thick and rested on Boulder Clay. This was the only instance in which I saw any stones included in the deposit.

South of the stream running west from Willingham this sand occurs only in patches, most of which are confined to the hollows. Most of these can only be detected by the difference of the soil, which of course in a heavy clay country is very marked. In a field half a mile west-south-west of the Beck House I saw some drains being cut to a depth of about 4 feet in a fine yellow and white sand, uniform throughout, and without stones, grit, or bedding. In this case it rested on the south-east side of the valley, but elsewhere it occurs indifferently on either side of the valleys.

About Barkwith and Panton the sand sends long tongues up the valleys, and runs up some of the gentler slopes. A small pit by the side of the road south-south-east of Panton shows fine ashy-grey sand becoming bright yellow below, to a depth of 3 feet. South-east of Panton House it forms a patch on the north-west side of a broad flat of stiff blue clay, and is partly banked up to the north-west. On the other hand, in the valley occupied by the railway between Barkwith and Willingham it is banked up against the south-east

side. The last patches occur near the Midge Inn on the Horncastle and Wragby Road. South of this locality there is a broad stretch of Boulder Clay country free from post-Glacial deposits.

A similar origin may be ascribed to a portion of the great spread of sand and gravel about Tattershall and Kirkby Moor previously described. It has been previously stated that this spread, as a whole, may be considered an estuarine gravel of the ancient Trent and its tributaries. It is probable that blown sand bordered this area at the time of the deposition of the gravel. Further supplies have probably been derived from the Witham estuary since the country assumed its present configuration, and, as in the case of the Ancholme, before the tide was banked out. Whatever its source, however, it is certain that much of the upper sandy part of the deposit owes its distribution to the action of the wind, and, therefore, strictly speaking, comes within the class of the more recent post-Glacial deposits. From the nature of the case it has been difficult to draw a hard and fast line between the more ancient estuarine sands and gravels, and the blown sand alluded to here.

A deposit of similar origin borders the Trent on the east side from near Collingham northwards, as noted by Mr. Cameron. Near Wigsley it has been drifted as far as the Rhætic outcrop, about a mile and a half from the margin of the Alluvium, and may be seen banked up against the windward side of the hedges. At Torksey Station also the number of small sand-dunes is referred to by Mr. Cameron as a noticeable feature. In some places the sand has been swept off the underlying Red Marl, so as to leave patches of this rock bare here and there. Near Saxelby Gibbet brown finely laminated sand was noted by Mr. Penning, which may be also partly of this origin.

The description of these sands is continued by Mr. Ussher as follows:—

A tract of considerable but very irregular extent on the eastern margin of the Trent Alluvium, from Knaith northwards, is occupied by sand. Where the sand is in contact with the Alluvium it undoubtedly passes under it, and is, therefore, earlier; it may be considered as a comparatively recent post-Glacial deposit, formed at a time when the tide had access further inland than now. It is not possible, however, to distinguish what portion of it is of estuarine origin, for the surface has probably been sifted over and over again by Æolian action, as is in many cases clearly proved by the dune-like form of the ground. From the low-lying tracts the sand has been irregularly blown upward over more elevated ground to the east, as in the case of the sand-patch between Gainsborough, Lea Station, and the higher ground near Knaith.

The origin of some of the sand-patches shown on the Map, as that near Stow and Sturton, the small patch near Thurlby Wood House, and parts of the sand near Lea Station and Knaith Park Farm, is rendered very doubtful by the strong probability of

sand-beds being intercalated in the Boulder Clay over the Liassic area. South of Lea Station the sand may have been derived from such intercalations.

At Marton brown sand obscures the junction of the Keuper and Rhætic beds; and occurs on the low cliff of Keuper Marls at Littleborough so irregularly as to simulate an appearance of inosculation with the Marls. At three-quarters of a mile from Lea Station 5 feet of brown sand in horizontal layers is seen resting on the Keuper Marls. Three-quarters of a mile south of Lea Station it conceals the surface of Boulder Clay, and apparently overlies the same deposit nearer to Knaith, and again towards the north at Lea Wood. The continuity of these patches of clay is very doubtful, for on the east of Lea Station the sand appears to rest on Lias Clay, and towards Gainsborough on Keuper Marl. The prevalent tint of this sand when unmixed with vegetable matter is a pale straw colour. Near Knaith, where it is exposed to a depth of 8 feet, it has a pale reddish hue. On the south of this village it forms uneven hummocky ground. An outlying patch occurs on a hill of Keuper Marl east of Trinity Church, Gainsborough; and on the south of Sonerby Hall an irregular patch of brownish sand occurs in the valley.

The most remarkable of the low-level sand-patches is that merging into the Trent Alluvium between Walkerith Ferry, Blyton, and Gainsborough, and continuing along the alluvial margin to a little south of Knaith. This sand mantles irregularly up the lower slopes of the Keuper Marl hills, attaining a considerable height near Knaith and Gainsborough Union House. The soil between Wharton Gate and Swansea Sewer Bridge (on the northern margin of the Sheet) as far as Morton is a black peaty sand forming a perfectly flat tract, from which the sands on either side rise very gently.

West of Swansea Sewer Bridge the sand is orange-brown, and towards Walkerith Ferry pale-buff as seen to a depth of 5 feet. Near the cemetery between Morton and Gainsborough it appears to be gravelly.

West of the Trent valley we are struck with the paucity of sandy deposits. The junction of the Triassic sandstone with the Marl is obscured by a sand probably derived from the sandstone and blown over the immediate neighbourhood. Near Field House the geology is rendered very indefinite by such sand.

W. A. E. U.

RIVER-GRAVELS AND TERRACES.

(1.) *The Bain Gravels.*

The greatest development of river-terraces in the eastern portion of the Sheet is found along the valley of the Bain from near Baumber southwards. The valley, as already stated, has been cut by the river through a thick mass of white Boulder Clay. In its upper reaches the valley extends partly into the Kimeridge Clay; about Horncastle it touches the surface of this clay, but south of this town it has not reached the base of the Boulder Clay. Before the valley had been excavated to its present depth, the gradients of the river were of course considerably steeper than at the present time, and as a consequence gravel was transported and spread out in the form of alluvial flats. By later erosion the river has formed a fresh set of alluvial flats at a lower level, over which for the most part silt mixed with gravel is now being distributed. The older gravel flats have thus come to occupy the position of terraces, fringing at a slightly higher level the modern Alluvium. In the tributary streams the gradient is still such as enables the stream to distribute gravel. It thus happens that the

old terrace-gravel of the Bain is found to merge insensibly into the partly newer valley-gravel of some of the tributaries, as at Haltham and Dalderby.

Commencing at the north end of this series of terraces, we find a small pit near Hemingby on the east side of the river, showing flint-gravel resting on clay but much obscured by slipping. One mile and a half further south there is a small opening by the side of the road in a similar deposit. Near this point there was formerly a brick-kiln in a narrow strip of Kimeridge Clay, which comes to the surface in the small slope separating the terrace from the modern alluvial flat. The valley of the Bain in this part is broad with a steepish slope of Boulder Clay on the west side, but with long gentle undulations of gravel on the east side, rising gradually up to the Boulder Clay hills, and ending off with a very indefinite boundary on their flanks.

The brick-pit south of Thimbleby House shows that the river-gravel here consists of 2-4 feet of sand and gravel, occasionally filling deep troughs in the surface of the Kimeridge clay.

At Horncastle the Bain is joined by a tributary on the east side known as the Waring. On the gravels which fringe the two streams and on the low neck of Boulder Clay which separates them, the greater part of the town is built.

About a mile up the Waring, near Low Toynton, there is a large pit in a terrace of flint-gravel.

About two miles south of Horncastle on the east side of the Bain there is a pit in a gravel terrace about six feet above the modern Alluvium. The gravel consists of well stratified beds of angular flints and loose gritty sand, alternating with bands of sand. There are a few white and Red Chalk pebbles, but about 98 per cent. of the stones are flints. In the river-bed close by, the gravel is seen to rest on hard white Boulder Clay, weathering to a yellowish colour, except when it is penetrated by rootlets, and bleached by the vegetable acids.

The following description of the terraces further south are from the notebook of Mr. Jukes-Browne:—

By Dalderby Lock, on the west side of the river, there is a patch of gravel rising slightly above the level of the surrounding Alluvium. A strip of gravel also bounds the east side of the Alluvium at and south of the hamlet of Dalderby, but no exposures were visible at the time of our visit.

The series is continued again on the opposite side of the valley below Roughton House, and thence extends without interruption through Kirkby to Coningsby and Tattershall, the only other place where gravel occurs on the east side of the river being near Haltham, where a small tributary beck comes in from the north-east.

Half a mile south of Roughton Church there is a small pit showing flint-gravel covered by loam and sand, and the workmen stated that they occasionally found bones in the former.

Road material has been obtained from several shallow excavations in the gravel-flat between the Bain and Haltham Beck, but the depth of the deposit does not seem to be great.

At Kirkby, between the road and the river, three furlongs north-west of the church, there is a deeper pit where the following beds were seen in October 1878:—

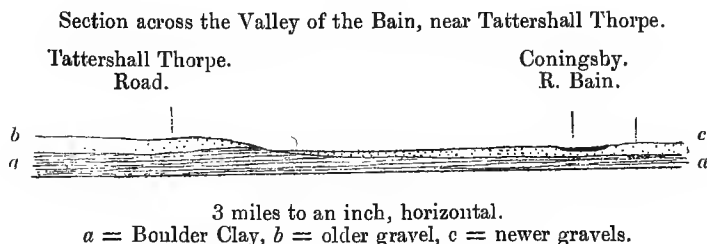
	Fr.
Alluvial soil	2
Yellow loamy sand	4
Rough flint gravel	3
Yellow loamy clay	1
	<hr/>
	10
	<hr/>

The last named was said by the workmen to be about 2 feet thick, and to rest on a blue clay "with chalk-stones." The bed of gravel thickened westwards to 4 or 5 feet, and the loamy sand above correspondingly diminished. No stones but flints were to be seen, and much dirty sand was mixed with the gravel. Two molar teeth of *Elephas primigenius* from this pit are in the possession of Mr. Fox of Coningsby.

South of Kirkby a low terrace formed of yellow and pink sand intervenes between the Alluvium and a still higher terrace which appears to connect itself with the older series by Tattershall Thorpe. The dotted line on the map indicates the rise of ground between these two platforms, and marks the limit of the deposits formed by the river Bain, since it was confined to its present valley.

A small excavation on the north side of the road half a mile west-north-west of Tattershall Mill showed 6 feet of sandy gravel (consisting almost entirely of flints with an occasional quartz pebble) overlying deep Boulder Clay; at the north end of the same field clay had been dug, the overlying gravel being only 3 feet thick, so that near the boundary line the Boulder Clay comes very near the surface; and this appears to be the case along the whole line, the older sands deepening to the north-west, while the newer deposits thicken towards the river; a section across the Bain Valley at this point would therefore appear as follows:—

FIG. 6.



Flint gravel has been dug on the east side of the Bain opposite Tattershall Mill, but southward the country between the Rivers Witham and Bain is covered with sand and sandy gravel, containing stones of all kinds derived from the Boulder Clay and from the older gravels which probably once extended over this ground.

This great spread of sandy material has probably been re-arranged by the currents of the Witham estuary when the Fenland was an open bay (see Explanation of Sheet 70).

A. J. J. B.

(2.) *Tributary Valley Gravels of the Witham.*

Langworth beck and its tributaries were found by Mr. Cameron to be also fringed with low gravel terraces, either a few feet above, or indistinguishable from, the modern Alluvium.

He states that the bridge at Snarford, having been destroyed by floods, was rebuilt in 1882-3. In digging for the foundations, the following deposits were met with:—

	Ft.
Flinty gravel and sand with thin clay seams	- 10
Blue "dicey" clay (? Oxford Clay)	- 18

There is a shallow pit about one mile from Langworth, in a gravel-flat bordering the stream from Holton. It shows from $\frac{1}{2}$ to 1 foot of loamy wash with freshwater shells, overlying roughly stratified flint gravel. The deposit is but little above the present level of the stream, and appears to be of recent origin. On crossing the Langworth beck to the east, the valley gravels in the tributaries are found to consist almost exclusively of Oolitic débris, which must have been carried down eastwards from the slopes of the Oolitic hills for a distance of a mile or more into the Boulder Clay area. Mr. Cameron notes a small pit on the north side of Langworth Station where the gravel is made up almost exclusively of pebbles of Oolitic limestones. Mr. Dalton states that the alluvial flats between Dunholme and Saxby also consist of this Oolitic débris with a few flints derived from the Boulder Clay.

The Alluvium of the Langworth, on the other hand, is mostly flint gravel, interspersed with shelly peat, travertine, and clay in patches.

On the south-west of Langworth Bridge a brick-pit shows an interesting section of a gravelly deposit with bones. The section is as follows:—

	Fr.
Angular gravelly soil in hollows and pockets, with fragments of freshwater and land shells	- - 2-4
Gravelly and hard blue clay with ice-scratched pebbles of chalk and flint and fragments of <i>Gryphæa</i> , and containing freshwater shells and bones of <i>Cervus elaphus</i> and <i>Bos primigenius</i>	- - 1-3
Blue loamy clay, thinning out to the north	- - 0-3
Oxford Clay.	

A collection of the shells was made by Mr. Clement Reid, and identified as follows:—

Unio pictorum, *Pisidium amnicum*, *Bythinia tentaculata*, *Valvata piscinalis*, *Planorbis* sp.?, *Succinea* sp.?, (abundant), and *Helix hispida*.

The shells, bones, and glaciated chalk pebbles all occurred fairly imbedded in the blue clay. But for the existence of the two first, and for the fact that it is in parts far more stony and gravelly than the true Boulder Clay of the district, this blue clay might well have been mistaken for a Glacial Deposit.* It is, in fact, evidently made up almost entirely of the materials of Boulder Clay, re-arranged probably by the Langworth beck when flowing at a considerably higher level than now. No Boulder Clay is seen in the pit, but it is probable that in the other portions of the low hill, in the side of which the pit is opened, Boulder Clay may occur in place. It is clear from the freshness of the scratches on the chalk pebbles that the materials have not been moved far.

In the blue loamy clay there occur specimens of Oxford Clay fossils, *Ammonites*, *Avicula*, and *Belemnites*. It is probably a wash from the surface of the Oxford Clay in the immediate neighbourhood.

On the south side, of the Witham near Heighington, a sand flat of alluvial origin has been found by Mr. Dalton to occupy a hollow lying between gravel-capped hills of Lower Oolite on the west, and a projecting shoulder of Boulder Clay on the east. Near Common Square there is some evidence of the wind having had a share in the distributing of the sand, but over too small an area to map as "blown sand." A valley gravel of small Oolitic fragments has been noted by Mr. Penning in the valley east of Dunston on the west side of the Witham, and again between Metheringham and Blankney by Mr. Dalton, who remarks that this great spread is in large measure due to the ease with which the Lincolnshire Limestone breaks into small flakes under the influence of frost. The hollow south of Ton Barf, north-east of Nocton, is occupied in the upper part by sand with stones derived from the Kellaways Rock and Cornbrash; in the lower part nearer the fen by peaty Alluvium abounding in freshwater and land shells.

(3.) *Trent Gravels.*

The Alluvium of the Trent is bordered by gravel terraces, at a height varying from 5 to 15 feet above the marsh-level, from Dunham all along the upper part of its course. The gravels almost everywhere consist principally of quartzite pebbles embedded in a gritty sand. The origin of the pebbles has been discussed above (p. 147).

Near Clifton Harbour, however, the remains of an old gravel of a more local character are seen banked up against a cliff of Keuper Marl at a height of about 15 feet above the modern

* Mr. Cameron is inclined to regard it as a true Boulder Clay.

Alluvium. The gravel is horizontally stratified, and presents the following section, as noted by Mr. Cameron :—

	Ft.
Red soil with fragments of coarse grey sandstone.	
Alternation of fine and coarse gravel, made up of rounded fragments of Triassic marl and sandstone	5
Laminated yellow clay - - -	$\frac{1}{2}$
Sand with carbonaceous streaks - - -	2
Fine sand and gravel, as above - - -	2 +
	<hr/> 9½ <hr/>

ALLUVIUM, PEAT, AND FEN-SILT.

The Witham and its Tributaries.

The recent Alluvium of the Witham and its tributary the Till, covers a considerable area at and west of Lincoln. It consists of bog, peaty sand, or marsh clay, according to local circumstances. These deposits, which form the lowest marshy flats, rest upon and fill up the shallow hollows in the undulating surface of a deposit of sand with a gravelly base, with a thickness, near Lincoln, varying from 20 to 40 feet.

A series of borings through these deposits was made in 1879-80 for the Great Northern and Great Eastern Railways Joint Committee, and will be found quoted in the Appendix.

Borings Nos. 7-11 and 20 commence in the recent Alluvium of the Witham below Lincoln, as indicated on the map (Fig. 7).

The average height of the Alluvium above Ordnance Datum is here 12 feet, and the surface consists of black and brown bog and dirty sand to a depth of 2-14 feet. This rests on yellow and white sand, in part quick with water, and becoming gravelly at the base, with an average thickness of 26 feet. Below these, the hard blue clay (Lias) is found at an average depth of 17 feet below Ordnance Datum.

Borings Nos. 6 and 12-15 commence in the low terrace of sand which fringes the Alluvium of the Witham on the south. The average height of this terrace above Ordnance Datum is 18 feet, or 6 feet above the lowest alluvial flat (see section, fig. 8). The deposit consists of white sand occasionally brown or reddish, water-logged in parts and gravelly towards the base.

It averages 35 feet in thickness, and rests on Lias at an average depth (not including boring No. 6) of 20 feet below Ordnance Datum, the greatest depth actually proved being 23·41 feet in boring No. 13, near the High Street. In boring No. 6, which is clearly at the margin of the deep channel, the Lias was found at 10·18 feet above Ordnance Datum.

Borings Nos. 16-19 are in the alluvial tract which borders the Witham near St. Peter's at Gowts, and extends along the foss-dyke north-westwards. The average elevation of this alluvial tract is 13 feet above Ordnance Datum.

The deposits are, generally speaking, the same as in Nos. 8-11, except that no bog was found in No. 16, about 2 furlongs west-south-west of St. Peter's Church, while in Nos. 18-19 it was found below a thickness of 2½ and 5 feet of sand, which had probably been recently washed or blown over it.

A bed of red clay 3 feet 9 inches thick was found in No. 15. It is probably alluvial and not Glacial.

The blue clay (Lias) in boring No. 18 (situated at the letter n of the word Drain) was proved at 15·70 feet below Ordnance Datum, but seems to rise from here towards the north-west, for in No. 19, nearly abreast of the Grand Stand, it was found at only 6·36 feet below Ordnance Datum.

FIG. 7.

Map showing the Positions of Borings in the Alluvial Deposits of the Rivers Witham and Till, near Lincoln.

Scale, one inch to a mile.

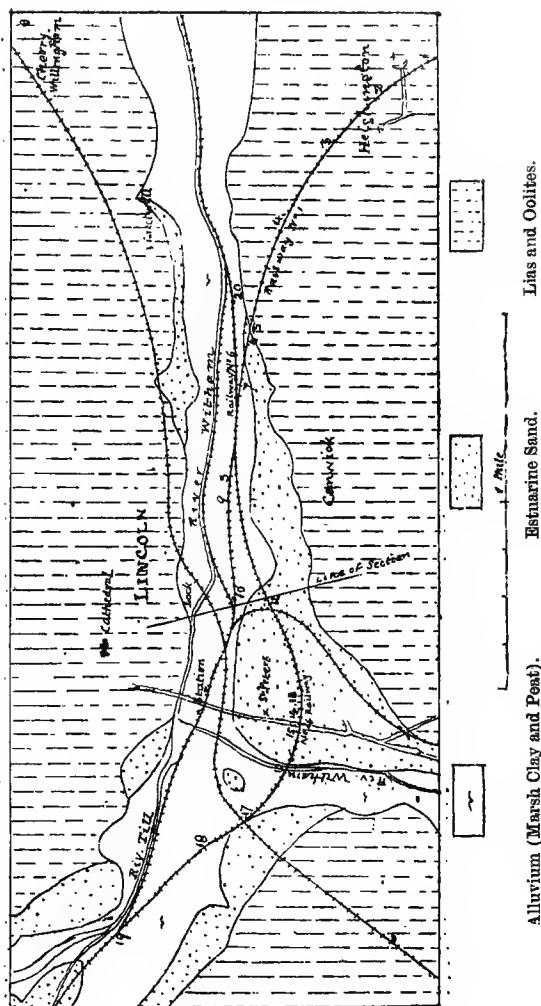
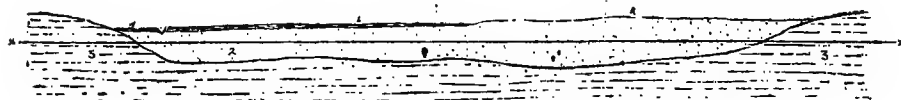


FIG. 8.

Section across the Valley of the River Witham, half-a-mile east of the G.N.R. Station, Lincoln.

W.N.W. R. Witham. Near Boring No. 11. Near Boring No. 12. S.S.E.



Horizontal Scale, 6 inches = 1 mile ; vertical scale 5 times exaggerated.

1, Peat and Alluvium. 2, Estuarine sand. 3, Lias.
× Ordnance Datum.

The pier foundations of the Midland Railway-bridge over the River Witham, were carried to a depth of 31 feet, through sand and gravel containing a bed of black peaty clay, 4 or 5 feet thick, with freshwater shells.

The cylinders of the railway bridge crossing the High Street in St. Peter's at Gowts were sunk to a depth of 50 feet in the following deposits:—

	Ft.
Made ground - - - - -	8-10
Sand, upwards of - - - - -	40
Gravel.	

and in the drainage works close by were found:—

	Ft.
Made ground with human bones at the base - - - - -	6-8
Sand - - - - -	12-15

In Roby's Foundry two tube-wells proved*:—

	Ft.
Made ground - - - - -	3
Fine silver sand - - - - -	5
Coarser sand - - - - -	26
Lias Clay - - - - -	16 +
	<hr/> 50 <hr/>

The wells are 3-inch bores, and are 5 yards apart. The yield is 25 gallons per minute from each well, the water standing during dry weather at $5\frac{1}{2}$ feet from the surface of the ground, up to which level the sand is water-logged.

At the new gasworks on west side of the Lincoln and Grantham line, near the 128th milestone, the base of the sand was reached at 5 feet. The Lias rises to the surface at a few yards distance.

Further details concerning these sections and borings will be found in the Appendix.

In the course of the Bracebridge reclamation works the following sections in the Alluvium of the Witham were exposed†:—

No. 1.—About $1\frac{1}{2}$ furlongs north-west of Bracebridge Church.

	Ft. In.
Yellow alluvial clay - - - - -	1 6
Yellow alluvial sand - - - - -	2 0
Peat (water stands) - - - - -	2 0 +
	<hr/> 5 6 <hr/>

Two rows of piles, 10 feet apart, are sunk in the peat, and rise at present about 2 feet above the water. A stone causeway has at one time rested upon them, and the place has been a ford across the Witham. Fragments of the causeway, broken pottery, a gold coin, and a portion of a human skull have been found.

No. 2.—South of No. 1.

	Ft. In.
Yellow alluvial clay - - - - -	1 0
Peat - - - - -	2 4
	<hr/> 3 4 <hr/>

* Communicated to Mr. Cameron by Mr. Collett, Engineer to the Works.

† Communicated to Mr. Cameron by Mr. Clarke, Bracebridge Hall.

have been the case at some period is proved by the depth below Ordnance Datum, at which the surface of the Lias is found clean swept of all Glacial Deposits, in and to the west of the Lincoln gorge. (See Section, Fig. 8.) A slow subsidence of the land to its present level would then account for the gradual filling up of the old channels in the Lias with an estuarine sand.

No organic remains have been observed in this sand, but bones and teeth of Rhinoceros have been found at Mr. Foster's pit, which, it was thought, may have been derived from this bed.

It may be noticed that the sand is occasionally compacted in patches by oxide of iron, deposited probably by water holding carbonate of iron in solution, in consequence of the escape of a portion of the carbonic acid into the air. Such patches may be observed on the plain west of Lincoln and on the Racecourse. Similar compacted masses of sand and grit have been noted by Mr. Penning on the south of the road between Navenby village and station, several feet below the outcrop of the Northampton Sand.

The description of the alluvial deposits of the lower part of the Witham valley, which forms an arm of the fen-land, is continued by Mr. Jukes-Browne thus :—

Between Bardney Drove and Nocton Delph the width of the fen-level is about three miles ; below the latter dyke it widens again slightly, and then preserves an average width of between three and four miles for some distance.

Anyone who makes a careful survey of this portion of the fen district may satisfy himself of the three following circumstances : 1, that the depth of turf is greater along the borders of the fen than along the medial line ; 2, that the level of the medial part is slightly higher than the rest ; 3, that the sub-soil of this medial part differs from that underlying the lateral portions.

The drainage of the fens has caused such a decrease in the thickness of the turf, that along the central part no trace is left beyond a few inches of black soil, and the sub-soil here is a soft silty or sandy clay, in which marine shells are occasionally found. The greatest depth of peat (from 2 to 3 feet) remains along the strip of ground called the Dales, between the Witham and the Dales Head Dyke ; this is explained by the fact that it formerly would serve as a "*wash*" for the overflow of the river in flood-time, and having, therefore, been taken into cultivation later than the rest of the fen, the turf has not yet shrunk to such an extent as elsewhere.

The central strip of silty land appears to commence in Washingbrough Fen, and has been traced southward through the fen, gradually increasing in width till it passes into the sheet to the south, the dotted lines on the map approximately indicating its boundaries. Being slightly higher than the land on either side it suffers less damage in times of flood.

Well sections at points within these lines show that the silt is from 14 to 20 feet in depth, and is underlaid by gravel or sand ; outside this district the wells are generally dug through

clean buttery clay from 12 to 16 feet thick, and often containing a peaty layer near its base, with gravel or sand below. As the latter deposit is never pierced we have no means of knowing the depth of this part of the Witham Valley. The following is a diagrammatic section across it from Martin to Kirkstead, constructed from such data as we possess:—

FIG. 9.

Diagrammatic Section across the Witham Valley, near Kirkstead.



a = sand and gravel. *b* = buttery clay, &c. *c* = silt.

Horizontal scale, 1 inch to 1 mile. Vertical scale, 1 inch to 200 feet.

It would appear, therefore, that while the buttery clay with its turfy layer was being formed, a channel or creek was kept open along the middle of the fen; this was probably open to the scour of the tide coming up from the estuary of the Wash, and was silted up at a much more recent date. It may indeed have been the channel by which the vessels of the Romans proceeded to their port of Lindum Colonia (Lincoln).

The character of the ordinary fen clay may be seen in a small brickyard half a mile north-north-east of the hamlet called Tanvats on Metheringham Delph. There is about a foot of peaty soil, and below this a soft clay somewhat silty for the first 2 feet, and containing stalks and leaves of plants, but passing down into a stiffer clean "buttery" clay which has been dug for 7 feet. The depth from the surface to the red sand under the clay hereabouts is said to be about 15 or 16 feet.

The nature of the silt may be seen in an excavation on the north side of Timberland Delph, 7 furlongs from Martin Wood, about 4 feet of fine soft laminated silt was visible here in 1878, containing marine shells, *Cardium edule*, *Mytilus edulis*, and *Tellina balthica*; the silty land here forms a tract about a mile in width, and is quite destitute of any turfy covering.

There are very few places in the fen where the sub-soil is neither silt nor clay, but there are some spots where gravel immediately underlies the peat or "turf," as it is called in Lincolnshire, and where this occurs the land is far poorer and less valuable than where there is an argillaceous sub-soil.

A strip of land along the fen-border opposite Nocton and Metheringham is underlaid by gravel, and a small gravel-pit about a quarter of a mile from the western end of Dunston Drove exposed the following section:—

	Fr.
Turfy soil - - - - -	0½
Sandy gravel - - - - -	4
Brown clay - - - - -	1

The gravel is almost entirely composed of small fragments of Oolitic limestone, the only other stones being a few small flints. The material has clearly been brought down by the brooks draining the Oolitic district to the westward, and similar fragments may be seen in the beds of the present stream south of Nocton Wood. This gravel area must, therefore, be viewed as the delta of these streams, and is probably spread out over the surface of the

buttery clay. Gravel also underlies the peat for a small space bordering Nocton Delph, west of the engine or pumping-mill. This would appear to be caused by a bank of the basement gravel here rising up and cutting out the intervening clay, for this appears to be very thin all round; thus the well at the cottage near the engine was dug through the following beds (according to the tenant):—

Soil and turf	-	-	-	-	-	Fr.
Clean clay	-	-	-	-	-	2½
Gravel	-	-	-	-	-	1½
						7
						<hr/>
						11
						<hr/>

The excavations for the foundations of the newly-built house on Dunston Drove half a mile south-south-west of the engine were dug down to the gravel, the section being thus:—

Turfy soil	-	-	-	-	-	Fr.
Layer of peat	-	-	-	-	-	2
Soft clay	-	-	-	-	-	1
Gravel	-	-	-	-	-	2½
						0½
						<hr/>
						6
						<hr/>

Mr. Penning also notes the following section in a brickyard, 1¼ miles south of Bardney Station:—

Black peaty soil	-	-	-	-	-	Fr.
Grey clay, silty in places, with plant-remains, sedges,						1 to 1½
&c., and wood in its lower part						
Gravel	-	-	-	-	-	5 to 6
						<hr/>

And at the two farms about a mile north-west of Bardney:—

Turf	-	-	-	-	-	Fr.
Clay	-	-	-	-	-	3 to 4
Bears-muck (clay with decaying vegetable matter)	-	-	-	-	-	1 to 0½
						<hr/>

The flat-bottomed valleys of the little streams, which drain the country on the east side of the Witham, form inlets of the fen, and seem in former times to have nourished a vigorous growth of forest trees. Many oak-trunks have been dug up from time to time in these bottoms, and some of the cottagers use the wood for fuel, calling it "blackwood." It cannot be used to make stakes or posts, as it rots away in the ground, but cross-bars or railings are sometimes made from it.

A good section of peat 2 to 3 feet thick, containing numerous large trunks of oak and birch, and largely made up of small wood, is afforded by the brick-pit near Bardney Station, previously referred to (p. 134). The peat rests in part on a blue clay with pockets of gravel, and in part on some patches of sand and gravel, which appear to be a down-wash from the quartzite gravel about Bardney.

By Bucknall Beck, opposite Hare Booth, the beds met with in digging a drain are reported to have been as follows:—

"Peaty warp," with trees	-	-	-	-	Fr.
"Buttery clay"	-	-	-	-	4
Fine reddish sand below	-	-	-	-	2
					?

It was also stated by my informant that some of the oak-trunks taken out here were over 50 feet long; I saw pieces of oak, sallow, and ? yew.

The ditches in the fen-inlet north of Kirkstead also disclose similar beds, clay underlying peat, but in the inlet north-west of Tattershall Lodge, the

subjacent material is sand; there is an old clay pit now filled with water in which the succession seems to be thus:—

Peaty soil.
Yellow sand.
Dark Boulder Clay.

Several trunks of black oak are lying round the pit, and attest the ancient forest growth along the fen edge.

On the opposite side of the fen, half a mile east-north-east of Timberland Church there is a large brickyard disclosing the excellent section previously mentioned (p. 137).

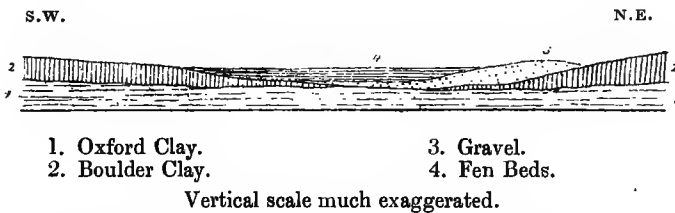
The vertical section in the middle of this shows:—

	Ft.
Peaty soil in places - - - -	0 to 0½
Silty clay - - - -	4 to 7
Peat, with oak, saw, and hazel nuts	0½
Sandy gravel - - - -	3 to 2
Boulder Clay - - - -	3 to 2
Oxford Clay - - - -	6 +
Dug to about -	17

The silty clay everywhere contains *Scrobicularia piperata*, and in one place it is crowded with specimens of *Rissoa ulvæ* (old and young); *Tellina balthica* also occurs. This clay thins out westward and allows the gravel to take the ground, so that a section across the hollow would appear as follows:—

FIG. 10.

Diagrammatic section across an inlet of the Fen near Timberland.



Northward also the clay thins out underneath the peaty soil, which overlies gravel in a pit near the extremity of the inlet. The gravel contains a mixture of stones derived from the Boulder Clay and high level gravels of the vicinity, pebbles of chalk and flint being mixed with those of quartz, quartzite, and lydian stone.

The valley of the little stream which descends westwards from Cold Harbour (near Tattershall) towards the Witham, is occupied for some distance by peat which varies in thickness from 7 inches to 2½ feet. Many trees occur in it, always oaks, some measuring 36 feet in length and 5 feet in circumference at the bole. They lie in all directions, sometimes across one another, and always occur on the surface of the underlying sand. This sand is 4 or 5 feet thick and rests on Boulder clay of a dark blue colour. From the railway to the Witham a little buttery clay intervenes between the peat and the sand. The portion north-east of the railway was only reclaimed in 1864, and is still called Rush Close from the growth of rushes there when it was a bog.

Near the point where the stream crosses the field-road, clay-pits were opened showing:—

	Ft.
Sand and gravel - - - -	4
Clay with uneven surface - - - -	3
Dark blue Boulder Clay, with chalk and occasional large boulders measuring 3 × 2 ft. - - - -	9
	16

A. J. J. B.

The Ancholme and its Tributaries.

The boundaries of the very irregular spread of marsh-deposits distributed by this river have been drawn on the west and east by Messrs. Jukes-Browne and Ussher respectively; they have been already alluded to in the description of the Ancholme valley low-level Glacial (?) clay.

One and a half miles south of the point where the Ancholme Canal enters the sheet, Mr. Ussher observed the subjoined section:—

	Ft.
Dark brown alluvial clay, about - - -	$\frac{1}{2}$
Grey loam with delicate fresh-water shells - -	$1\frac{1}{2}$
Close gravel of rather small partially worn stones, chiefly flint - - -	$1\frac{1}{2}+$
	<hr/> $3\frac{1}{2}$ <hr/>

Borings have proved that further to the north (Sheet 86), the upper beds of the Alluvium are underlain at a depth of more than 20 feet by one or more beds of peat.

Some of the tributaries on the east bank have brought down large quantities of sand from the blown-sand areas about Market Rasen and Usselby.

Calcareous tufa occurs near the Neocomian and Chalk outcrops. Professor Judd remarks, "Near the upper waterfall in the gorge above Tealby, occurs an interesting deposit of travertine; the course of the stream has been changed at this place, and in the old river bed the deposit in question is seen; it is about 8 feet thick in its deepest part, but is of no great length. The lower part of the deposit is white and crumbling, the upper light-brown and hard; it contains very numerous plant-remains, and also shells of terrestrial mollusca, among which I recognized *Helicella nitida*, Müll., and *Succinea putris*, Linn."*

A similar deposit may be found round some of the springs from the Red Chalk near North Willingham.

The Trent and its Tributaries.

The boundaries of the Alluvium of the Trent have been drawn in the northern part of the sheet by Mr. Ussher, and in the southern part by Messrs. Dalton and Cameron.

Mr. Ussher remarks:—From Stockwith in the north to Littleborough it consists of brown or occasionally dark grey clay and loam. At Misterton Station and south of Walkeringham the lowest ground is bounded by a very gentle slope, covered in the latter case by a brown loam, and, therefore, included in the alluvial area; towards Beckingham the marls are overspread by a similar deposit, but too thin to be shown. The Alluvium of the two tributary streams south of Beckingham consists, in the upper reaches, of re-deposited grey marls, a section near North Wheatley showing:—

	Ft.
Red loam, with irregular patches of grey clay at the base - - -	3 to 5
Grey loamy clay with broken grey shales and marl, re-deposited - - -	2
Keuper Marls.	

* *Quart. Journ. Geol. Soc.*, xxiii., p. 244.

South of Trinity Church, Gainsborough, there appears to be a low river-terrace, about 5 feet above the Alluvium, and consisting of brown sand with worn stones; it is seen in the new road to the Ropery to rest on a red clay, apparently re-deposited marl. The gravelly sand near the cemetery between Morton and Gainsborough may be of the same origin.

The nature of the low-level Alluvium in this neighbourhood was ascertained by two boreholes made in 1881, on the east side of the Trent, 20 chains south of Gainsborough Bridge, in Ashcroft Field, near the Great Northern Railway Company's siding.*

No. 1.					No. 2.	
Soil	-	-	-	Fr.	Soil and warp	- 9
Warp	-	-	-	- 3	Peat and bog	- 21
Peat	-	-	-	- 7	Sand.	
Bog	-	-	-	- 9		
Gravel	-	-	-	- 5		
				<hr/>		<hr/>
				30		30
				<hr/>		<hr/>

W. A. E. U.

These borings may be compared with those made in the valley of the Ancholme (Explanation, Sheet 86) in which a peat-bed has been found at a considerable depth below the surface of the recent Alluvium.

In the southern part of this Sheet the lowest Alluvium of the Trent is found by Mr. Cameron to be bordered by low terraces of gravel, there being also islands of gravel or sand standing up above the marsh-level.

A well at Grassthorpe on the modern alluvial flat showed :—

Rich soil and peat	-	-	-	-	Fr.
Green moss†	-	-	-	-	10
Gravel, with bones of animals	-	-	-	-	$2\frac{1}{2}$
Clay and water	-	-	-	-	2
					<hr/>
					14 $\frac{1}{2}$
					<hr/>

The river in this part of its course is prevented from flooding the low ground on the east by artificial banks; the results of the bursting of these is referred to on pp. 148 and 174.

The Alluvium of the Tuxford, Egmont, Moorhouse, and Cauntun brooks, was found by Mr. Dalton to consist largely of tufa with a mere soil of sandy earth. The tufa is dug to a depth of 3 feet near Scaring Moor Mill for garden paths. It varies from fine loose calcareous powder to a hard coarse pisolite, with open spaces between the concretions. The more prevalent form is compact travertine with the calcified remains of aquatic plants and shells of fluviatile mollusca.

At Darlton Gaps on the slope of the Tuxford valley is a patch, a few acres in extent, of a species of half-formed gravel, composed of flakes of Triassic sandstone very slightly rounded at the edges, and bearing traces of pseudo-morphs on their sides. A few quartzite pebbles occur in the mass.

The Idle.

The River Idle, which joins the Trent at its junction with the Humber, flows for a short distance only within the western limit of this Sheet, though a considerable area is occupied by its alluvial deposits.

* Communicated by Mr. Atkinson.

† Described by the farmer, from whom the information was derived, as living.

From Hayton northwards, according to Mr. Ussher, the Alluvium consists of brown clay, peaty and loamy in places near Clayworth and Wiseton. It is bordered on the east by a low-lying tract of loam and clay; a section on the east bank of the canal, south of Clayworth Field, shows 5 feet of lead-coloured clay containing shells of *Helices*, and in one spot fine gravel. The Alluvium of the Clayworth tributary stream where it crosses the canal is 4 feet thick, and consists of brown earthy clay with land-shells, resting upon stiff grey clay with numerous quartzite pebbles, and a bone in its lower part; this rests upon gypseous marls (Keuper Marls). Higher up, the Alluvium consists of re-deposited marl. The Alluvium of the Wiseton tributary is of the same nature, with a terrace of gravelly loam on its north side.

Near the canal west of Clarborough a mass of tufa has been noticed by Mr. Cameron; it is apparently made up of the stems of *Characeæ* encrusted with lime, and of the shells of fresh-water mollusca.

The flat mapped as river-gravel, south of the alluvial tract, is stated by Mr. Dalton to consist of coarse red sand with occasional pebbles, being little more than the Bunter sandstone (on which it lies) disintegrated and roughly levelled, the wind taking an important part in the latter process. The gravel ridge running south from Retford, is considered by him to be an earlier deposit, formed before the erosion of the hollow on the east, or the formation of the present channel of the Idle on the west; it is exposed in a shallow pit by the side of the high road, 300 yards north-east of "Old Eel-pie House," showing 6 feet of red, yellow, and blackish sand; an outlying patch of the same deposit caps the hill on which the eastern part of the town stands, while a discontinuous terrace at a slightly lower level, but above the highest floods, may be seen near the station (Quarter-sheet 82 N.W.)

The alluvial tract occupying the north-western corner of the sheet is over-spread by a black peaty soil, but is fringed by brown loam or re-deposited Marls on its south and east margins.

Floods, with some registers of flood-marks. By A. G. Cameron.

The banks of the Trent have given way at different times at Newton, Torksey (where the Foss Dyke enters the Trent), Brampton, and Spaldford. In consequence of a break at the last-named village in February 1795, the flood waters of the Trent came to Lincoln, where they were only stopped by the fact of the High Street being artificially raised (probably by the Romans) from 12 to 15 feet above the surrounding land. About 20,000 acres to the west of the city were submerged.* Previously, in November 1770, the Foss Dyke embankment, at Torksey, had given way, the water coming to Lincoln and flooding the villages of Saxelby, Torksey, Brampton, Fenton, Kettlethorpe, Thorney, Skellingthorpe, and Boultham.

A horizontal line on the corner-stone of the Brownlow Arms, at Marnham Ferry, Trent-side, 4 feet above the surface of the ground, indicates the height to which the Trent rose in 1875.

On a slab inserted in a garden-wall facing the road through Girton village, is cut the following inscription:—

February 14th, 1795	3 feet.
October 24th, 1875	- 2 feet 6 inches.
November 20th, 1852	- 2 feet.

When you see this, pity me. G. P.

This village is yearly surrounded by floods, in some seasons for so long that provisions become exhausted, and have to be brought in boats from Collingham.

In the wall of Collingham churchyard is a stone bearing the inscription—

October 24th, 1875	-	-	3 feet 6 inches.
--------------------	---	---	------------------

On the high road from High Mellwood to Owston Ferry (Sheet 86) is a flagstone, with a flood-mark, dated Aug. 7th & 14th, 1857.

* "Fens and Floods of Mid-Lincolnshire," by J. S. Padley, County Surveyor of Roads and Bridges. Lincoln, 1881. (With plan.)

APPENDIX I.

SYNOPTICAL TABLES OF FOSSILS IN SHEET 83.

Table I.—Lower Lias.

,, II.—Middle Lias.

,, III.—Upper Lias.

,, IV.—Inferior Oolite.

,, V.—Great Oolite Series and Cornbrash.

These Tables have been prepared by Mr. W. A. E. Ussher, from lists of Fossils in the Survey Collection identified by Messrs. G. Sharman and E. T. Newton.

Table VI.—Kimeridge Clay Fossils. Compiled by Mr. Jukes-Browne from those given by Prof. J. F. Blake.

sp. affixed to genus means species not determinable.

TABLE I.—FOSSILS FROM THE LOWER LIAS.

	Pits $\frac{1}{2}$ mile E.S.E. of Collingham Station.	Ditch $\frac{1}{2}$ mile N. of Eagle Church.	In the Witham, 1 mile N. of Basingham Church.	Basingham Brick-yard.	Waddington† Station Pit.
PLANTÆ.					
Wood - -			.	.	*
ECHINODERMATA.					
Pentacrinus, sp.		- -	-	*	
BRACHIOPODA.					
Rhynchonella, sp. - -			*		
R. variabilis, Schot. - -		- -	-	-	*
Spiriferina Walcott, Sow. - -			*		
LAMELLIBRANCHIATA.					
Astarte, sp. - - -	-	*			
Avicula inæqualvis, Sow. - -	*	- -	-	*	
Cardium truncatum, Sow. - -	-	*		*	*
Cardinia Listeri, Stutch. - -	-				

† This column may include examples from the Middle Lias ; see page 21.

TABLE I.—FOSSILS FROM THE LOWER LIAS—*continued*.

	Pits $\frac{1}{2}$ mile E.S.E. of Collingham Station.	Ditch $\frac{1}{2}$ mile N. of Eagle Church.	In the Witham, 1 mile N. of Bassingham Church.	Bassingham Brick-yard.	Waddington† Station Pt.
LAMELLIBRANCHIATA— <i>cont.</i>					
Gervillia lævis, <i>Buckm.</i> -	‘		‘		*
Goniomya, sp.	-	*	*		*
Gryphæa arcuata, <i>Lam.</i> = <i>G. incurva</i> , <i>Sow.</i>				*	
<i>G. cymbium</i> , <i>Lam.</i> = <i>G. Maccullochii</i> , <i>Sow.</i>					*
<i>Leda galathea</i> ? <i>D' Orb.</i> -	-		*		
Lima, sp.					
<i>L. gigantea</i> , <i>Sow.</i>	*				
Lacina, sp.		*			
Modiola minima, <i>Sow.</i>	?				
<i>M. scalprum</i> , <i>Sow.</i>				*	*
<i>Monotis papyria</i> , <i>Quenst.</i>	*				*
<i>Ostrea</i> , sp. -		†	*		*
<i>O. liassica</i> , <i>Strickl.</i> -	*				*
<i>Pecten æquivalvis</i> , <i>Sow.</i>					*
<i>P. liasinus</i> , <i>Nyst.</i> -			*		?
<i>P. Thiollieri</i> , <i>Martin</i> -			*	*	*
<i>Pholadomya ambigua</i> , <i>Sow.</i>			*		
Pinna, sp.	-	-		*	
<i>P. Hartmanni</i> , <i>Ziet.</i>	-			*	
<i>Pleuromya</i> , sp.	*			*	*
<i>P. unioides</i> , <i>Röm.</i>				*	*
<i>Plicatula spinosa</i> , <i>Sow.</i>		-	-	-	*
<i>Unicardium</i> , sp. -		*	*	-	*
<i>U. cardioides</i> , <i>Phil.</i>	-				
GASTEROPODA.					
<i>Actæonina</i> , sp. -			*		*
<i>Chemnitzia liassica</i> , <i>Quenst.</i>		*			
<i>Cryptænia</i> , sp.		*			
<i>Eucyclus</i> , sp. -		*			
<i>E. gaudryanus</i> , <i>D' Orb.</i>	-		*		
<i>E. imbricatus</i> , <i>Sow.</i>	-		-		*
CEPHALOPODA.					
<i>Ammonites</i> , sp. -	-	*			
<i>A. capricornus</i> , <i>Schl.</i>			-		*
<i>A. planorbis</i> , <i>Sow.</i>	*				
<i>A. subplanicosta</i> , <i>Oppel.</i>	-			*	*
<i>A. striatus</i> , <i>Rein</i>			-		*
<i>Belemnites clavatus</i> , <i>Schl.</i>				-	*
Bone (fragment)	*				

† This column may include examples from the Middle Lias ; see page 21.

TABLE II.—FOSSILS FROM THE MIDDLE LIAS.

	Railway Cutting West of Coleby, Nodular Bed.	Bracebridge Brick Co.'s Pit. From Nodule Bed T. From below Nodule Bed +.	Kirk and Parry's Pit.	Drain in West Parade Road, Lincoln.	Glasier's Pit, $\frac{3}{4}$ mile W.N.W. of Lincoln.	Hemswell Brick Pit.	Marlstone Rock Bed.	
PLANTÆ.								
Wood	-	+	*	*				
ECHINODERMATA.								
Crinoid fragments	-	+	-	-	*			
CRUSTACEA.								
Crustacean fragments	-		*					
BRACHIOPODA.								
Lingula, sp.	-		-	-	*			
Rhynchonella, sp.	-	+						
Terebratula, sp.	-	-	-	-	-		*	*
Waldheimia perforata, <i>Piette</i>	-	T +						
LAMELLIBRANCHIATA.								
Arca Stricklandi, <i>Tate</i>	-	-	*					
Arcomya?	-	-	-	-	*			
Astarte, sp.	-	-	*	-	-		*	
Avicula, sp.	-	-	-	-	-			
A. cygnipes, <i>Phil.</i>	-	T	*	-	-			
A. inæquivalvis, <i>Sow.</i>	-	-	*	-	*			
Cardinia Listeri, <i>Stutch.</i>	-	-	-	-	-		*	*
C. crassiuscula, <i>Stutch.</i>	-	-	-	-	-		*	
Cardita multicostrata, <i>Phil.</i>	-	*	-	-	*		*	
Cardium, sp.	-	-	-	-	-	*		
C. truncatum, <i>Sow.</i>	-	*	+	*	-	*		
Ceromya liassica, <i>Moore</i>	-	-	T					
Goniomya, sp.	-	-	-	*	-	*		
G. hybrida, <i>Münst.</i>	-	*	+ ?		*			
Gresslya, sp.	-	-	+	-				
G. donaciformis <i>Phil.</i>	-	-	T +					
G. intermedia, <i>Simps.</i>	-	-	+					
G. Seebachii, <i>Brauns.</i>	-	-	+					
Gryphæa ? fragment	-	-	-	-	-		*	
Hippopodium, sp.	-	-	-	*				
H. ponderosum, <i>Sow.</i>	-	-	+					
Inoceramus, sp.	-	-	-	*				
Leda graphica, <i>Tate</i>	-	-	+	*				
L. imbricata, <i>S. & N.</i>	-	-	+	*	-	*		

TABLE II.—FOSSILS FROM THE MIDDLE LIAS—*cont.*

	Railway Cutting West of Coleby, Nodular Bed.	Bracebridge Brick Co.'s Pit. From Nodule Bed T. From below Nodule Bed +.	Kirk and Parry's Pit.	Drain in West Parade Road, Lincoln.	Glasier's Pit, $\frac{3}{4}$ mile W.N.W. of Lincoln.	Henswell Brick Pit.	Ditch between North and South Carlton.	Marlstone Rock Bed. Stream, $\frac{1}{2}$ mile S. of Fillingham and $\frac{3}{4}$ mile N. of Ingham.
LAMELLIBRANCHIATA—<i>cont.</i>								
<i>Lima</i> , sp. - - -	-			*	-	-	*	
<i>L. gigantea</i> , Sow.	-	+						
<i>L. pectinoides</i> , Sow. -	-	+						
<i>Lithodomus</i> , sp.	-			*	-	*	*	
<i>Modiola scalprum</i> , Sow. -	-	+		*	-			
<i>Ostrea</i> , sp. - -	-			*				
<i>O. irregularis</i> , Münster.	-	+	*					
<i>Pecten</i> , sp. -	-	-		*	*			
<i>P. æquivalvis</i> , Sow.	-	+			-	-	*	
<i>P. substriatus</i> , Röm.	-	-			-			*
<i>Pecten liasinus</i> , Nyst.	*	+	*					
<i>Pholadomya</i> , sp.	-	+						
<i>Pleuromya</i> , sp.	-	-			-	*		
<i>P. unioides</i> , Röm. -	-	T +						
<i>Plicatula spinosa</i> , Sow. -	-	T						
<i>Unicardium cardioides</i> , Phil.	-	T + ?		-	-	-	*	
GASTEROPODA.								
<i>Chemnitzia</i> ? sp. - -	-	-	*					
<i>C. semitecta</i> ? Tate = <i>C. sublineatum</i> , Moore.	-	-		-	-		*	
<i>Eucyclus imbricatus</i> , Sow. -	*	T +	*	*				
<i>Pleurotomaria</i> , sp.	-	-	-	-	-	-	*	
<i>Turbo</i> , sp. - -	-	T						
<i>T. cyclostoma</i> , Benz.	*							
CEPHALOPODA.								
<i>Ammonites</i> , sp. -	-	-	-	-	*	*		
<i>A. capricornus</i> , Schl.	-	-	+					
<i>A. communis</i> , Sow.	-	-		-	-	-		
<i>A. nitescens</i> , Y. & B. -	-	-	+	*	-	-	-	*
<i>A. msrgaratus</i> , Montf.	-	*	T +	*				
<i>A. striatus</i> , Rein.	-	-	+					
<i>Belemnites</i> , sp. -	*	T	-	*	*	*	-	*
<i>B. breviformis</i> , Voltz.	-	-	-	-	-	-	*	
<i>B. clavatus</i> , Schl.	-	-	+					
<i>B. vulgaris</i> , Y. & B. -	-	-	T					
Bone (fragment) -	-	+						

TABLE III.—FOSSILS FROM THE UPPER LIAS.

	Clay and Limestone Bands, Insect Limestone, Pit $\frac{1}{8}$ mile E.S.E. of Navenby Station. Old Brickyard below Coleby.	Blue Clays above Trigonia Bed.	Trigonia Bed, Calca- reous Shale.	Clays between Trigo- nia and Lucina Bed.	Lucina Bed.	Limestone in Blue Clays at base of Upper Lias.	Trigonia Bed, Calca- reous Shale.	Lucina Bed, Calca- reous Shale.	Blue Clay, with bands of septarian nodules, below Lucina Bed.
Best's Pit.									
Swan's Pit.									
PLANTÆ.									
Wood	-	-	-	*	-	-	-	-	-
ECHINODERMATA.									
Pentacrinus	-	-	-	-	-	-	-	*	-
ANNELIDA.									
Serpula plicatilis, Goldf.	-	-	*	-	-	-	*	-	-
BRACHIOPODA.									
Discina reflexa, Sow.	-	-	-	-	-	*	-	-	*
Rhynchonella Bouchardii, Dav.	-	-	-	-	-	-	-	*	-
LAMELLIBRANCHIATA.									
Arca, sp.	-	-	-	-	-	-	*	-	-
Avicula, sp.	-	-	-	-	-	-	-	-	-
Astarte camertonensis, Moore.	-	-	*	-	-	-	*	*	-
A. lurida ? Sow.	-	*	-	-	-	-	-	-	-
Cucullæa ferruginea, Lyc.	-	-	-	*	-	-	*	-	-
Inoceramus, sp.	-	*	-	-	-	*	-	-	*
Lucina, sp.	-	-	-	-	-	-	-	*	*
Monotis substriata, Zeit. = Avicula nitescens, Simps.	-	-	-	-	-	-	-	*	*
Myacites arenacca, Ag.	-	*	-	*	-	-	*	*	-
Nucula, sp.	-	-	-	*	-	-	*	-	-
Ostrea, sp.	-	-	-	*	-	-	*	-	-
Pecten, sp.	-	-	-	-	-	-	-	*	-
Posidonomya Bronnii, Voltz.	*	-	-	-	-	*	-	-	?
Trigonia pulchella, Ag.	-	-	-	*	-	-	*	*	-
GASTEROPODA.									
Actæonina, sp.	-	-	-	-	-	-	-	*	-
Amberleya, sp.	-	-	-	*	-	-	-	-	-
Cerithium, sp.	-	*	-	-	-	-	-	*	-
C. near to C. granulato- costatum ? Münst.	-	-	-	-	*	-	*	-	-
Chemnitzia, sp.	-	-	-	-	*	-	*	-	-
Dentalium minutum, Strick.	-	-	-	-	-	*	-	*	-
Dischælix, sp.	-	-	-	*	-	-	*	*	-
Monodonta, sp.	-	?	-	-	-	-	*	*	-
Pleurotomaria subdecorata, Münst.	-	-	-	-	-	-	-	*	-
Tornatella, sp.	-	-	-	-	-	-	-	*	-
Trochus tiarellus, Tate = T. similis, Moore.	-	*	-	*	-	-	*	-	-

TABLE III.—FOSSILS FROM THE UPPER LIAS—*cont.*

	Clay and Limestone Bands, Insect Limestone, Pit $\frac{1}{2}$ mile E.S.E. of Navenby Station.	Old Brickyard below Coleby.	Best's Pit.					Swan's Pit.		
			Blue Clays above Trigonia Bed.	Trigonia Bed, Calca- reous Shale.	Clays between Trigo- nia and Lucina Bed.	Lucina Bed.	Limestone in Blue Clays at base of Upper Lias.	Trigonia Bed, Calca- reous Shale.	Lucina Bed, Calca- reous Shale.	Blue Clay, with bands of septarian nodules, below Lucina Bed.
CEPHALOPODA.										
Ammonites annulatus, Sow.	-	*	*							
A. bifrons, Phil.	-	*	*	*						
A. communis, Sow.	-	*	*							
A. complanatus? Brug.	-	*	*							
A. crassus, Phil.	-								*	
A. dispansus, Lyc.	-							*		
A. fimbriatus, Sow.	-		var			*				
A. heterophyllus, Sow.	-		*							
A. Levisoni, Simps.	-									*
A. serpentinus, Rein.	-									
A. striatulus? Sow. (frag- ment).	-	*							?	*
Belemnites, sp.	-	*				*		*		
B. Voltzii, Phil.	-			*						
B. vulgaris, Y. & B.	-		*							
Nautilus striatus, Sow.	-					?		*		
REPTILIA.										
Ichthyosaurus (vertebra) -	-		*							

The following were subsequently obtained from Best's Pit:—

Ammonites sub-carinata, Y. & B.

A. Holandrei, D'Orb.

A. Serpentinus, Rein.

A. semicelatus, Simps.

From Swan's Pit—*Inoceramus*, sp.

TABLE IV.—FOSSILS FROM THE INFERIOR OOLITE—continued.

LAMELLIBRANCHIATA.—cont.	
Gervillia aurita? <i>Lyc.</i>	
Lina, sp. "	
L. bellula? <i>Lyc.</i>	
L. cardiiformis, <i>Sow.</i>	
L. duplicata, <i>Sow.</i>	
L. gibbosa, <i>Sow.</i>	
L. pectiniiformis, <i>Schl.</i>	
L. punctata, <i>Sow.</i>	
Ostrea, sp.	
O. gregaria, <i>Sow.</i>	
O. sulcifera, <i>Phil.</i>	
Pecten annulatus, <i>Sow.</i>	
P. articulatus, <i>Schl.</i> (fragment)	
P. demissus, <i>Phil.</i>	
P. lens, <i>Sow.</i>	
P. paradoxus, <i>Münst.</i>	
P. personatus, <i>Goldf.</i>	
Pinna (fragment)	

TABLE IV.—FOSSILS FROM THE INFERIOR OOLITE—continued.

[illegible]

TABLE V.—FOSSILS FROM THE GREAT OOLITE SERIES.

	Upper Estuarine.		Great Oolite Limestone.		Cornbrash.	
	Greetwell Railway cutting, 2 miles E. of Lincoln.	Greetwell Railway cutting, 2 miles E. of Lincoln.	Ditch Section, near Nettleham Lodge, 2 miles E.N.E. of Lincoln.	$\frac{1}{4}$ mile E. of Church, Chery Willingham.	Sudbrook Holme Park, over 4 miles E.N.E. of Lincoln.	Normanby (by Spital) neighbourhood.
Cœlenterata.						
Cladophyllia, sp.	-	*				
Isastrea, sp. -		*				
Echinodermata.						
Acrosalenia, sp.	-	-	-	-	-	*
A. Wiltonii, Wright	-	-	-	-	*	*
A. spinosa, Ag.	-	-	-	-	*	*
Anabacia orbulites, D'Orb.	-	-	-	-	*	*
Clypeus Plotii, Klein	-	-	-	-	*	*
Echinobrissus clunicularis, Lhuys.	-	-	-	-	*	*
E. orbicularis, Phil.	-	-	-	-	*	*
Holcotypus depressus, Leshe	-	-	-	-		*
Pseudodiadema, sp.	-	*				
Annelida.						
Serpula, sp. -	-	-	*	*		
S. tricarinata? Sow.	-	-	-	-	*	
S. convoluta, Goldf.	-	-	-	-	*	
S. deplexa, Bean.	-	-	-	-	*	
Brachiofoda.						
Rhynchonella, sp.	-	*				
R. conceinna, Sow.	-	-	*	-	*	*
R. Morieri? Dav.	-	-	-	-	*	
R. varians, Schl.	-	-	*	*		
Terebratula intermedia, Sow.	-	-	-	-	*	*
T. maxillata? Sow.	-	-	*	*		
Waldheimia obovata, Sow.	-	-	-	-	*	*
W. ornithocephala, Sow.	-	-	-	-	*	
Lamellibranchiata.						
Anomia, sp. -	-	-	*			
Avicula echinata, Sow.	-	*	*		*	
Astarte	-	-	*			
A. unguata, Phil.	-	-	-		*	
Ceromya concentrica, Sow.	-	-	-		*	
Gervillia, sp.	-	-	*		*	
Goniomya v. scripta, Goldf.	-	-	-		*	
Gresslya, sp. -	-	-	-	*		
G. peregrina, Phil.	-	-	-	*	*	
Isocardia?	-	*				
Isocardia tenera, Sow.	-	-	-		*	
Lima gibbosa, Sow.	-	-	-		*	
L. rigidula, Phil.	-	-	-		*	
Lucina burtonensis, Lyc.	-	-	-		*	
Modiola, sp.	-	*	-			

TABLE V.—FOSSILS FROM THE GREAT OOLITE SERIES—*continued*.

	Upper Estuarine.	Great Oolite Limestone.	Cornbrash.			
	Greetwell Railway cutting, 2 miles E. of Lincoln.	Greetwell Railway cutting, 2 miles E. of Lincoln.	Ditch Section, near Nettleham Lodge, 2 miles E.N.E. of Lincoln.	$\frac{1}{4}$ mile E. of Church, Cherry Willing- ham.	Sudbrook Holme Park, over 4 miles E.N.E. of Lincoln.	Normanby (by Spital) neighbourhood.
LAMELLIBRANCHIATA—cont.						
M. bipartita, Sow. -	-				*	
M. imbricata, Sow. - -	-	*	*		*	
Myacites, sp. -		?	-	*		
M. calceiformis, Phil. -	-		-		*	
M. decurtata, Goldf. -	-			-	*	
Nucula, sp. -	-				*	
Opis ?	-		*	-		*
Ostrea acuminata, Sow. -		*			*	
O. flabelloides, Lam.		-			*	
O. Sowerbyi, Lyc. & Mor. -	*	*	*		*	
O. subrugulosa, Lyc. & Mor.	-	*	*		*	
Pecten annulatus ? Sow.		*				
P. articulatus, Schl.	-	-	-		*	
P. demissus, Phil.	-				*	
P. lens, Sow. -	-	-		-	*	
P. vagans, Sow.					*	
Pholadomya acuticosta, Sow.	*				*	
P. deltoidea, Sow. -		-	-	-	*	
P. lyrata, Sow. -	-	-	-		*	
P. oblita ? Lyc. & Mor. -	-	-	-	-	*	
Placunopsis, sp.			-		*	
Plicatula ? -	-	*				
Pholadomya ovalis, Sow. -	-	-	-	-	*	
P. parvula, Röm. -	-	-	-	-	*	
Quenstedtia lævigata, Phil.	-	-				*
Tancredia ? -	-	-	*			
Trigonia costata ? Sow.	-	*				
T. conjungens ? Phil. -	-		*			
T. elongata, Sow. -	-	-	-	-	*	
T. Moretonis, Lyc. & Mor. -	-	-	-		*	
T. scarburgensis, Lyc. -	-	-	-		*	
T. like undulata -	-	-	-			*
Unicardium gibbosum, Lyc. & Mor.	-	*	-			
GASTEROPODA.						
Alaria armata ?, Lyc. & Mor.	-	-	-	-	*	
Chemnitzia, sp. -	-	-	-	-	*	
Natica punctura, Bean. -	-	-	-	-	*	
Nerinea, sp. -	-	-	-	-	*	
Pleurotomaria, sp.	-	-	-	-	*	
CEPHALOPODA.						
Ammonites Bakeriæ, Sow. -	-	-	-	-	*	
A. macrocephalus, Schl. -	-	-	-	-	*	
PISCES.						
Acrodus, sp. -	-	*	-	-	*	

TABLE VI.—FOSSILS from the KIMERIDGE CLAY compiled from those given by Professor J. F. BLAKE.

The specimens marked thus * are in the Woodwardian Museum.

	Woodhall.	Langton.	Baumber.	Horncastle.	Market Rasen.
*Ichthyosaurus, sp.	-	-	-	-	x
*Teleosaurus, sp.	-	-	-	-	x
Ammonites Berryeri, Les.	-	x	-	-	x
*A. biplex, Sow.	-	-	x	-	x
A. cymodyce, D'Orb.	-	-	-	-	x
A. decipiens, Sow.	-	-	x	-	x
*A. mutabilis, Sow.	-	-	-	x	x
*A. serratus, Sow.	x	x	x	-	x
A. hector, D'Orb.	-	-	x	-	-
*Belemnites nitidus, Dollf.	x	-	-	-	x
*Cerithium crebrum, Bla.	-	-	-	x	x
*C. forticostatum, Bla.	-	-	-	-	x
Rostellaria mosensis, Buv.	-	x	-	x	-
*R. rasensis, Bla.	-	-	-	-	x
Rissoa mosensis, Buv.	x	-	-	-	-
Natica microscopica, Cont.	-	-	-	-	x
*N. punctulata, Bla.	-	-	-	-	x
Dentalium Quenstedti, Bla.	-	-	-	x	x
*Neritopsis delphinula, D'Orb.	-	-	-	-	x
Tornatella secalina, Buv.	-	-	-	-	x
Arca longipunctata, Bia.	-	-	-	-	x
A. mosensis, Buv.	-	-	-	-	x
A. reticulata, Bla.	-	-	-	x	x
A. rhomboidalis, Cont.	-	x	x	-	-
Astarte Michaudiana, D'Orb.	-	-	x	-	x
A. ovata, Sow.	-	-	-	-	x
*A. supracorallina, D'Orb.	?	-	-	x	x
Anatina parvula, Et.	-	-	-	-	x
A. minuta, Bla.	-	-	-	x	-
Anomia Dollfusii, Bla.	-	-	x	-	x
Avicula ædiligensis, Bla.	x	x	-	x	-
A. dorsetensis, Bla.	-	x	-	-	-
*Cardium striatulum, Sow.	-	-	-	x	x
Corbula Deshayesia, Buv.	-	-	x	x	x
C. fallax, Cont.	-	-	x	-	-
Ceromya orbicularis, Röm.	-	-	x	-	-
Cyprina cyreniformis, Bla.	-	x	-	-	x
Exogyra nana, Sow.	-	-	-	-	x
Homomya compressa, Ag.	-	-	x	x	-
*Inoceramus expansus, Bla.	-	-	-	-	x
*Leda lineata, Bla.	-	-	-	-	x
Lucina minuscula, Bla.	-	-	-	-	x
Lima ædiligensis, Bla.	x	-	x	-	-
Nucula Menkii, Röm.	-	x	x	x	x
N. obliquata, Bla.	-	x	-	-	x
N. sp.	-	-	-	x	-
*Ostrea deltoidea, Sow.	x	-	-	-	x
O. gibbosa, Les.	-	-	-	-	x
O. monsbeliardensis, Cont.	-	-	-	-	x
Pecten demissus, Ph.	-	x	-	-	x
P. Grenieri, Cont.	-	-	x	x	x
P. Thurmanni, Cont.	-	-	-	-	x
P. arcuatus, Sow.	-	-	x	-	-
*Pinna, sp.	-	-	-	-	x

TABLE VI.—FOSSILS from the KIMERIDGE CLAY—*continued*.

	Woodhall.	Langton.	Baumber.	Horncastle.	Market Rasen.
<i>Pholadomya æqualis</i> , Sow.	-		-		x
* <i>Pholadidea abbreviata</i> , Bla.					x
* <i>Thracia depressa</i> , Sow.	x			x	x
* <i>Trigonia juddiana</i> , Lyc.					x
<i>Lingula ovalis</i> , Sow.			x		x
* <i>Terebratula Gesneri</i> , Et.					x
<i>Discina elevata</i> , Bla.			x		
* <i>Hoploparia</i> , sp.					x
<i>Serpula tetragona</i> , Sow.	-	x			
<i>S. intestinalis</i> , Ph.	-				

APPENDIX II.

BY MR. A. STRAHAN.

WELL-SECTIONS AND BORINGS.

arranged, approximately with reference to the geological features of the district, in the following groups:—

- | | |
|---|---|
| 1. On the Triassic Area. | 5. On the southern part of the Kimeridge Clay Area. |
| 2. On the Liassic Area. | 6. On the Fens of the Witham. |
| 3. On or near the Oolite Escarpment. | 7. On the Chalk Area. |
| 4. On or near the Neocomian Escarpment. | |

The sections are numbered as below:—

Benniworth, 23.	Ludford, 45.
Boultham, 16.	Ludford Walk House, 44.
Burton, 6.	Market Stainton, 28.
Calsthorpe, 46.	Martin Fen, 41, 42.
Canwick, 17.	Martin North Drove, 38, 39.
Dalderby Farm, 29.	Metheringham Fen, 40.
Donnington, 20.	Retford, 2.
East Torrington, 27.	Scarle, 4.
Gainsboro*, 1.	Scothern Grange, 7.
Greetwell, 18.	Sixhills, 26.
Hainton Hall, 24.	South Willingham, 21, 22.
Hainton Walk Farm, 25.	Sudbrook Holme, 9.
Harebooth, 43.	Tattershall Park, 32.
Horncastle, 33.	Tuxford, 3.
Horsington, 30.	Washingborough, 19.
Ingham, 5.	Withcall Hill, 48.
Lambcroft, 47.	Wood Enderby, 31.
Langworth, 8.	Woodhall, 34.
Lincoln borings, 10.	Do. Moor, 37.
Do. well-sections, 11-15.	Do. Spa, 35, 36.

1. On the Triassic Area.

(1.) GAINSBORO* "WATER WORKS":—*

Well and boring.—The well is 58 feet deep. The borehole is lined with cast-iron tubes of 19 inches internal diameter to 140 feet, of 15 inches internal diameter to 212 feet, of 12½ inches internal diameter (wrought-iron) to 335 feet, of 10½ inches diameter (wrought-iron) to 737 feet, and of 10 inches diameter (wrought-iron) to 1,100 feet.

From the surface to 725 feet depth the well and boring were in Keuper marl, with much gypsum to a depth of 350 feet, but with very little gypsum below this depth. From 725 feet to 1,100 feet the boring was in sandstone, containing abundant red and white pebbles at 750 and 910 feet depth; the bottom of the boring is therefore probably in the Bunter Pebble Beds. The yield of water amounts to about 9,000 gallons per hour. The following is an analysis of the water obtained at a depth of 1,000 feet in September 1887:—

Total solid residue at 212° F. = 32.20 grains per gallon.

Combined chlorine = 1.40 grains per gallon.

Temporary hardness = 9.45

Permanent do. = 16.31

Total do. 25.76 (Clarke.)

* The information concerning this well and boring was kindly supplied by Mr. A. Timmins, C.E.

(2.) RETFORD:—In the Report of the British Association for 1880, p. 104, will be found the following:—

Section of strata at boring of Retford Coal Co.'s boring at East Retford, Notts:—

	Ft.	In.
Soft red marl and sandstone	11	6
Red and grey marl-stone and grey "pumice"*	30	6
Red sandstone	123	0
Grey and red marl	3	0
Red sandstone	92	6
Red sandstone and gravel	1	6
Red sandstone	230	0
Red marl and gravel	1	6
Red sandstone	142	6
Pebbles or conglomerate	8	0
Red sandstone	70	0
Red marl	3	0
Red sandstone	69	0
Red and grey marl mixed with red and white sandstone	99	0
Red marl and limestone	7	0
	902	0

(In addition to the ambiguity in the title, there appears to be some error in addition or in the record; these figures give a total depth of 892 feet.)

The beds proved in this boring are grouped by Mr. Dalton as below:—

	Ft.
Keuper	42
Bunter Pebble Beds	451½
Lower Bunter	292½
Permian	106

(3.) TUXFORD:—Well at the station, communicated to Mr. Dalton:—

Red marls and thin sandstones, 60 feet.

Water in sandstone.

There are several shallow wells in the village, with bad water.

2. On the Liassic Area.

(4.) THE SCARLE BORING:—Boring for Coal, about a mile E. by N. of Collingham Church (sometimes referred to as the Collingham, or the Swinderby section, or the Lincolnshire Coal Exploration). The site is on the Nottinghamshire side of the County boundary, and in North Collingham parish. This account is compiled by Mr. Dalton from the articles by Professor E. Hull† and Mr. E. Wilson,‡ with notes from Mr. J. T. Boot, engineer, and Mr. T. S. Bavin, superintendent, and from specimens. Cores of the boring down to a depth of 753 feet, were handed to Mr. Cameron by Mr. Page and Mr. Battle of Lincoln, and are now in the Museum of Practical Geology.

	Thickness.	Depth to Base.
	Ft.	Ft.
River gravel	21	21
Lias clay and limestone	29	50
Rhætic shales and sandstones	15	65
Keuper marls with gypsum	688	753
Keuper sandstones (water-bearing)	205½	958½
Bunter Pebble Beds	318½	1,277
Lower Bunter, marl, &c.	223	1,500

* Presumably a soft porous sandstone.

† *Proc. Inst. Civ. Eng.*, vol. xlix., p. 160, 1877.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 813, 1879.

					Depth to	
					Thickness.	Base.
					Fr.	Fr.
Permian, 519 ft.	Marls	-	-	-	118½	1,618½
	Magnesian limestone	-	-	-	43½	1,662
	Marl and sandstone	-	-	-	150	1,812
	Magnesian limestone	-	-	-	68	1,880
	Sandstone	-	-	-	20	1,900
	Marl slates	-	-	-	118	2,018
	Coarse grit and breccia	-	-	-	1	2,019
	Coal measure shales	-	-	-	12	2,031

(For details of lithological character and yield of water, see pp. 3-6.)

Mr. Ussher remarks that this account will be found to differ from the published accounts in several respects, Mr. Dalton having obtained information from Mr. T. S. Bavin, upon which he felt justified in revising the published account of Professor Hull.

The thickness of 66 feet assigned to the Rhætic (doubtfully) by Professor Hull, is probably excessive. Mr. Dalton took the first indication of gypsum in the cores as evidence of the Rhætic, and regarded the green siliceous grits in the cores referred by Professor Hull to the Rhætic, as belonging to the Keuper. Mr. Ussher, bearing in view that the Rhætic beds are from 20 to 30 ft. thick in the Lea cutting, is inclined to assign to them a greater thickness than 15 feet at Scarle.

(5.) INGHAM :—

Wells and Trial-holes. Communicated by Mr. J. W. Radcliffe to Mr. Dalton.

1. *The Green.*

	FT.	IN.
Clay and soil	-	3 6
Clay with limestone	-	1 6
Ironstone clay	-	4 0
Dry laminated clay.		

2. *Back of houses, N. of the Green.*

Soil	-	1 0
Dirty clay	-	2 0
Dark clay with limestones, a few sand-creeks, no water	-	7 0

3. *Back of houses, opposite the road to Lincoln.*

Garden soil	-	1 0
Clayey soil	-	1 6
Dark clay with small limestone nodules, which fell to pieces on exposure	-	3 6
Ironstone clay	-	1 0
Laminated clay.		

4. *West of road to Lincoln.*

Garden soil	-	1 0
Dirty clay	-	1 6
Dark clay with limestone nodules	-	6 0
Laminated clay.		

5, 6, *West end of space west of Church.*

<i>S. side of road.</i>		
Made earth	-	1 0
Laminated clay	-	5 0
<i>N. side of road.</i>		
Fine earth	-	3 0
Red sand	-	2 0
Laminated clay.		

		Ft.	In.
7. <i>Public Well, N.W. of Church.</i>			
Soil	-	-	1 0
Sand	-	-	1 8
Yellow clay	-	-	1 10
Laminated clay	-	-	7 6
Water level 6 feet from surface.			

8. *Churchyard.*

Mould	-	-	1 ft. to	1 6
Sand, wet	-	-	-	1 6
Stiff yellow clay.				

(6.) BURTON:—

Middle Low Field; communicated by Mr. Watkins, Lincoln, to Mr. Cameron.

		Ft.	In.
Gravelly top soil.			
Blue shale (Lias)	-	-	60 0
			<hr/> 60 0

Burton Flats. Evans Farm Steading.

		Ft.	In.
Sand with water	-	-	10 0

3. *On or near the Oolite Escarpment.*

(7.) SCOTHERN GRANGE WELL.

		Ft.
Boulder clay	-	7
Gravel, with water.		
		<hr/> 7

(8.) LANGWORTH:—Farm a quarter of a mile south-west of the Station.

		Ft.
Boulder clay	} sunk	30
Oxford clay		
„	bored to sand	30
		<hr/> 60
Kellaways Sand reached at		

The water rises nearly to the surface.

(9.) SUDBROOK HOLME:—

Communicated by Messrs. Legrand and Sutcliff. Water rises to top of house. Yields 7,000 gallons per day of 10 hours.

		Ft.	In.
Soil	-	-	2 0
Kellaways Beds.	{ Stone	-	5 0
	{ Grey sand	-	13 0
	{ Blue clay	-	7 0
Cornbrash	- Stone	-	4 6
Great Oolite	{ Green clay	-	11 6
	{ Dark clay	-	14 0
Great Oolite	{ Stone	-	4 0
	{ Clay	-	1 0
	{ Shell rock	-	14 6
Upper Estuarine.	{ Green clay	-	3 8
	{ Stone	-	5 4
Lincolnshire Limestone.	{ Clay	-	15 0
	{ Stone	-	5 6
			<hr/> 106 0

(10.) LINCOLN :—

The following series of borings was made in 1879–80 for the Great Northern and Great Eastern Railways Joint Committee. They were communicated to Mr. Cameron by Mr. Samuel Abbott, C.E., of Lincoln. Nos. 1–4 were each made through ground which was removed in making the cuttings of the railway at Washingbrough and Heighington (see pp. 39, 50, 63, 66). The position of each boring is shown on the map forming Fig. 8.

No. 5 Boring, at 35 miles 75 chains from Spalding Railway No. 1. Above Ordnance Datum, 25·39 feet.

	Ft.	In.
Soil - - - - -	-	4 0
Earth and small stones (not gravel); water	-	3 6
	<hr/>	<hr/>
	7	6

No. 6 Boring, at 35 miles 79 chains 60 feet from Spalding, Railway No. 1. Above Ordnance Datum, 21·01 feet.

	Ft.	In.
Soil - - - - -	-	0 6
White stones or loose rock and a little sand	-	0 10
Yellow sand with water - - - - -	-	2 8
Yellow sand and small white stones, with water	-	3 6
Brown quick-sands - - - - -	-	3 4
Hard blue clay (10·18 feet above Ordnance Datum)	1	8
	<hr/>	<hr/>
	12	6

No. 7 Boring, at 36 miles 15 chains 49 feet from Spalding, Railway No. 1. Above Ordnance Datum, 14·41 feet.

	Ft.	In.
Boggy soil - - - - -	-	1 6
Dirty sand - - - - -	-	1 3
Yellow sand and small white rock-stones	-	1 11
Dirty yellow sand with water - - - - -	-	1 4
Brown quick-sands - - - - -	-	13 0
Quick-sands and small white rock-stones	-	3 0
Sharp sand and gravel - - - - -	-	1 0
Fine gravel - - - - -	-	2 0
Gravel and sharp sand - - - - -	-	1 6
Sharp sand and water - - - - -	-	5 6
Sharp sand - - - - -	-	1 9
Hard blue clay (19·34 feet below Ordnance Datum)	0	9 +
	<hr/>	<hr/>
	34	6

No. 8 Boring, at 36 miles 58 chains 10 feet from Spalding, Railway No. 1. Above Ordnance Datum, 12·52 feet.

	Ft.	In.
Black bog and soil - - - - -	-	2 6
Yellow sand - - - - -	-	1 0
Quick-sand - - - - -	-	18 0
Sharp sand and a little gravel - - - - -	-	7 4
Hard blue clay (16·31 feet below Ordnance Datum)	0	10 +
	<hr/>	<hr/>
	29	8

No. 9 Boring, at 36 miles 64 chains 51 feet from Spalding, Railway No. 1.
Above Ordnance Datum, 12'32 feet.

	Ft.	In.
Soil - - - - -	0	6
Black bog - - - - -	2	0
White sand - - - - -	0	6
Yellow sand - - - - -	1	0
Quick-sand - - - - -	14	0
Sharp sand with some water - - - - -	3	0
Sharp sand with a little gravel - - - - -	2	0
Sharp sand and gravel - - - - -	8	6
Hard blue clay (19'18 feet below Ordnance Datum)	1	2 +
	<hr/>	<hr/>
	32	8

No. 10 Boring, at 37 miles 28 chains 51 feet from Spalding, Railway No. 1. Above Ordnance Datum, 11'91 feet.

	Ft.	In.
Soil and dirty sand - - - - -	3	6
Yellow sand - - - - -	1	6
Quick-sand - - - - -	11	3
Sharp sand and gravel - - - - -	3	9
Black loam and sand - - - - -	2	3
Fine sand and very coarse gravel - - - - -	0	9
Sharp sand and gravel - - - - -	4	3
Hard blue clay (15'34 feet below Ordnance Datum)	1	0 +
	<hr/>	<hr/>
	28	3

No. 11 Boring, at 37 miles 39 chains 20 feet from Spalding, Railway No. 1. Above Ordnance Datum, 13'43 feet.

	Ft.	In.
Brown bog, &c. - - - - -	3	3
Black bog - - - - -	0	9
Dirty sand - - - - -	0	9
Yellow sand - - - - -	0	9
White sand - - - - -	1	3
Quick-sand - - - - -	9	7
Sharp sand and gravel with some water - - - - -	1	11
Sharp sand and a little coarse gravel - - - - -	12	5
Hard blue clay (17'24 feet below Ordnance Datum)	0	10 +
	<hr/>	<hr/>
	31	6

No. 12 Boring, at 65 chains 17 feet from Greetwell Junction, near Canwick, Railway No. 4. Above Ordnance Datum, 16'53 feet.

	Ft.	In.
Clean white sand, &c. - - - - -	2	4
Brown sand with some water, about - - - - -	2	8
Clean sharp sand, about - - - - -	1	0
Fine sand - - - - -	1	0
Bluish white sand - - - - -	1	6
Sharp loamy sand - - - - -	1	6
Fine brown loamy sand - - - - -	1	0
Quick-sands, about - - - - -	8	6
Sharp sands and a little gravel - - - - -	16	3
Hard blue clay (19'22 feet below Ordnance Datum)	0	11 +
	<hr/>	<hr/>
	36	8

No. 13 Boring, at 1 mile 24 chains 62 feet from Greetwell Junction, near Canwick, Railway No. 4. Above Ordnance Datum, 10·73 feet.

	Ft. In.
Reddish sand, &c. - - - - -	- 5 6
Gravel - - - - -	- 0 9
Red sand - - - - -	- 0 9
Soft blue clay and sand - - - - -	- 1 0
Sharp sand - - - - -	- 5 3
Sharp sand and a little gravel - - - - -	- 20 11
Hard blue clay (23·41 feet below Ordnance Datum)	0 4½ +
	<hr/> 34 6½

No. 14 Boring, at 1 mile 35 chains from Greetwell Junction, near Canwick, Railway No. 4 (on east side of the High Street). Above Ordnance Datum, 22·02 feet.

	Ft. In.
Dirty sand, &c. - - - - -	- 6 0
Shingly sand - - - - -	- 0 9
Sandy clay - - - - -	- 1 3
Yellow sand - - - - -	- 2 0
Quick-sand - - - - -	- 10 0
Coarse sand - - - - -	- 6 10
Coarse sand with a thin bed of fine gravel - - - - -	- 1 2
Coarse sand - - - - -	- 3 0
Hard gravel. Below Ordnance Datum, 9·73 feet	- 0 9 +
	<hr/> 31 9

No. 15 Boring, at 1 mile 37 chains 12 feet from Greetwell Junction, near Canwick, Railway No. 4 (on west side of the High Street). Above Ordnance Datum, 21·49 feet.

	Ft. In.
Dirty sand, &c. - - - - -	- 4 6
Clean sand - - - - -	- 0 9
Brown sand - - - - -	- 0 6
Sharp sand and a little bog - - - - -	0 3
Dirty sand - - - - -	- 1 3
Yellow sand - - - - -	- 1 9
Sharp sand and a little gravel with some water - - - - -	- 1 0
Sand with some water - - - - -	- 6 9
Soft red clay - - - - -	- 1 6
Soft red sandy clay - - - - -	- 1 6
Soft red clay - - - - -	- 0 6
Soft red sandy clay - - - - -	- 0 3
Gravel and sand - - - - -	- 3 6
Sharp sand and some water - - - - -	- 2 0
Sharp sand and a little gravel - - - - -	- 13 0
Hard blue clay (17·51 feet below Ordnance Datum)	0 8 +
	<hr/> 39 8

No. 16 Boring, at 1 mile 53 chains 45 feet from Greetwell Junction, near Canwick, Railway No. 4 (north side of the Witham). Above Ordnance Datum, 12·43 feet.

	Ft. In.
Dirty sand, &c. - - - - -	- 10 6
Dirty yellow sand and gravel - - - - -	- 0 6
Sharp sand - - - - -	- 1 6
Sharp sand and a little gravel - - - - -	- 17 10
Hard blue clay (17·9 feet below Ordnance Datum)	- 1 3 +
	<hr/> 31 7

No. 17 Boring, at 1 mile 79 chains $4\frac{3}{4}$ feet from Greetwell Junction, near Canwick, Railway No. 4. Above Ordnance Datum, 13·55 feet.

	Ft.	In.
Soil and white sand	-	2 0
Yellow sand	-	2 0
Quick-sand	-	8 0
Sharp sands and gravel	-	1 0
Sharp sand and a little gravel with some water	-	2 0
Sharp sand and a little gravel	-	16 2
Blue clay (17·61 feet below Ordnance Datum)	-	0 9 +
		<hr/>
		31 11

No. 18 Boring, at 2 miles 18 chains $52\frac{3}{4}$ feet from Greetwell Junction, near Canwick, Railway No. 4 (north side of Skellingthorpe Drain). Above Ordnance Datum, 12·55 feet.

	Ft.	In.
Soil	-	0 9
Yellow sand	-	1 9
Black bog	-	1 0
Pink sand	-	1 6
Quick-sand	-	5 0
Sharp sand and gravel	-	1 0
Clean fine gravel	-	1 6
Gravel	-	0 6
Sharp sand and gravel	-	15 3
Hard blue clay (15·70 feet below Ordnance Datum)	-	1 0 +
		<hr/>
		29 3

No. 19 Boring, at 3 miles 10 feet from Greetwell Junction, near Canwick, Railway No. 4. Above Ordnance Datum, 13·72 feet.

	Ft.	In.
Surface, &c.	-	5 0
Brown bog	-	1 0
Dirty white sand	-	2 0
Dirty sand	-	2 9
Sand and gravel	-	7 9
Sand and a little coarse gravel	-	1 7
Hard blue clay (6·36 feet below Ordnance Datum)	-	0 11 +
		<hr/>
		21 0

No. 20 Boring, at 9 chains $52\frac{3}{4}$ yards from Washingbrough Junction, Railway No. 6. Above Ordnance Datum, 8·45 feet.

	Ft.	In.
Soil	-	0 6
Brown bog	-	13 6
Dirty white sand	-	3 0
Dirty sand and gravel	-	4 0
Sharp sand and gravel and small white "rock-stones"	-	2 9
Hard blue clay (15·30 feet below Ordnance Datum)	-	1 3 +
		<hr/>
		25 0

- (11.) LINCOLN :—Crown Brewery Well, Waterside, South. Communicated by Mr. Teague.

Made ground	-	-	-	-	-	Ft.
Sand	-	-	-	-	-	7
Hard flinty gravel with water.						14
						<hr/> 21 <hr/>

- (12.) LINCOLN :—Well at No. 220, High Street. Communicated by Mr. Teague.

Made ground	-	-	-	-	-	Ft.
Old Roman Road (pavement, &c.)	-	-	-	-	-	18
Turf moor	-	-	-	-	-	2
Gravel with water.						15
						<hr/> 35 <hr/>

- (13.) LINCOLN :—Mr. Dawber's Brewery, Carholme Road. Communicated by Mr. Dawber.

Sand and gravel	-	-	-	-	-	Ft.
Lias clay	-	-	-	-	-	40
						140
						<hr/> 180 <hr/>

The well was sunk to the base of the sand and gravel, and the Lias was bored into to the further depth of 140 feet. No water having been obtained from the Lias, the boring was abandoned. The present supply, which is plentiful, is derived from the sand and gravel, the well being supplemented by connected tube-wells.

- (14.) LINCOLN :—Excavation for a new gas-holder, on west side of the Lincoln and Grantham Line, $1\frac{1}{2}$ furlongs north of the 128th mile post. Noted by Mr. Cameron.

Sand and rubbish	-	-	-	-	-	Ft.
Loamy clay, mottled blue and yellow with rootlets, passing into Lias	-	-	-	-	-	5
Lias clay with septaria (top of "capricornus zone" according to Mr. W. D. Carr)	-	-	-	-	-	6
Lias clay	-	-	-	-	-	4
						24 +
						<hr/> 39 <hr/>

- (15.) LINCOLN :—Cricket-field, Wragby Road.

Oolitic limestone	-	-	-	-	-	Ft.
Ironstone	-	-	-	-	-	5
						6

- (16.) **BOULTHAM** :—Trial boring for water on the site of the present filter-beds in use by the Lincoln Waterworks. Communicated by Mr. Teague to Mr. Cameron.

	Ft.
Soft mud - - - - -	6
Harder sand and clay with some water -	6
Very hard coarse sand - - - - -	8
Clay becoming very hard below - - - - -	17 +
	<hr/> 37

- (17.) **CANWICK** :—Lincoln Sewage Outfall Works. Noted by Mr. Penning.

	Ft. In.
Peat - - - - -	1 6
Clean sand - - - - -	12 6
Fine gravel or silt - - - - -	3 0
Hard sandy clay - - - - -	2 6
Coarse quartzite gravel - - - - -	8 0
	<hr/> 27 6

Sundry bones were found at about 12 feet down.

- (18.) **GREETWELL** :—On the hill north of the railway cutting.

	Ft.
Oolitic limestone - - - - -	65
Limestone.	

- (19.) **WASHINGBROUGH** :—In a field a furlong west of the church.

	Ft.
Oolitic limestone to water - - - - -	42

4. *On or near the Neocomian Escarpment.*

- (20.) **DONNINGTON** :—A boring by Mr. Bogg in search of coal.

“*Notitiæ Ludæ*,” or “*Notices of Louth*.” London. 1834. Anon.
Chapter III.—Geological Appearances.

	Yds.	Ft.	In.
1. A clay soil -	1	0	0
2. Dark coloured clay - - - - -	3	0	0
3. Soft grey slate with marine impressions -	0	1	0
4. Blue argillaceous stone - - - - -	0	0	5
5. Dark coloured clay - - - - -	1	0	1
6. Soft grey slate - - - - -	0	1	0
7. Laminated clay, slightly indurated -	7	2	0
8. Soft grey slate, slightly inflammable -	1	2	3
9. Do. do. do., dark coloured	1	2	3
10. Indurated clay, with white marine organic remains - - - - -	12	1	6
11. Indurated clay, with white marine organic remains, harder and blacker - - - - -	2	1	3
12. Dark bitumenous inflammable schist -	2	0	0
13. Dark blue coloured ironstone - - - - -	0	0	3
14. Laminated indurated clay, with white organic remains - - - - -	11	0	0
15. As No. 11, harder, marine impressions of thin leafy pyrites - - - - -	3	1	4
16. Dark blue argillaceous stone - - - - -	0	0	4
17. As No. 14 - - - - -	6	0	4

Carried forward -

	Yds.	Ft.	In.
Brought forward -			
18. Laminated bitumenous schist, with white marine organic remains, inflammable -	0	1	10
19. Dark blue ironstone -	0	0	2
20. As No. 18 -	3	2	0
21. As No. 19 -	0	0	1½
22. As No. 20 -	6	0	10½
23. As No. 10 -	1	0	6
24. As No. 22 -	3	0	0
25. As No. 23 -	2	2	0
26. As No. 24 -	1	1	6
27. As No. 25, intermixed with thin seams of bitumenous schist -	10	0	3
28. Grit -	0	0	2
29. Brown laminated schist -	0	0	2
30. Hardstone bind or argillaceous stone -	0	2	10
31. Hard laminated bitumenous schist -	0	1	2
32. As No. 30 -	0	2	0
33. Nearly as No. 31 -	0	2	4
34. Inflammable slaty bind -	1	0	0
35. As No. 33, very inflammable -	1	0	7½
36. Hard dark blue bind, interlaid with thin strata of bitumenous schist -	4	1	9½
37. Very inflammable schist -	0	0	2
38. As No. 36 -	1	0	8
39. Argillaceous stone -	0	1	0
40. Softer do. -	0	1	0
41. As No. 36 -	7	1	10
	103	0	0

at which (103 yards deep) boring was discontinued.

This boring was commenced in the upper part of the Kimeridge Clay, a few feet below the base of the Spilsby Sandstone, and was probably still in the Kimeridge Clay when it was abandoned.

(21.) SOUTH WILLINGHAM :—At Mr. Fieldsend's, Belmont, on the east side of the "High Street," south of the road from South Willingham to Donnington-on-Bain.*

	Fr.
White marl -	6
Clean white sand -	15
Pipe clay and sand -	39
Sharp sand [? Spilsby sandstone] -	15
	75

(22.) SOUTH WILLINGHAM :—About 100 yards east of the church.*

	Fr.
White marl -	15
Blue clay with chalk and flints -	18
Blue shale [Kimeridge clay]. †	
	33

(23.) BENNIWORTH VILLAGE :—About 300 yards west of the church.*

	Fr.
White marl -	30
Blue and white clay mixed -	12
Black shale with dice (water rose quickly).	
	42

* Well-section communicated by Mr. James Freeborough, well-sinker.

(24.) Hainton Hall Stables.*

	Ft.
White marl - - - - -	30
Blue clay with chalk and flints - - -	15
Blue shale [Kimeridge clay].	
	<hr/> 45

(25.) Hainton Walk Farm:—One mile south-east of Sixhills.*

	Ft.
Yellow fine clay - - - - -	15
Blue stone [Tealby Limestone] - - -	12
Blue and white clay [Tealby Clay] - - -	33 +
	<hr/> 60

A boring was put down to a further depth of 60 feet, passing through soft blue clay and reaching soft sand, presumably the top of the Spilsby Sandstone.

(26.) Sixhills:—At Mr. Drake's, close to the church.*

	Ft.
White marl, about - - - - -	17
Blue clay with chalk - - - - -	30
	<hr/> 47

(27.) East Torrington:—Mr. Trafford's.*

	Ft.
Yellow clay - - - - -	4-5
Blue clay, with stones [Kimeridge clay with septaria].	

There was bad air with a sulphurous smell in this well. Water is often found in the beds containing the septarian stones, and in the bands of "dice."

(28.) Market Stainton:—House near the church.†

	Ft.
Bored through white clay, with sand below - - -	80

5. On the southern part of the Kimeridge Clay Area.

(29.) Dalderby Farm:—Belonging to Sir H. Dymoke. Communicated by Mr. Dobbs of Kirkstead, well-sinker.

	Ft.
Sunk through white clay full of stones - - -	60
Bored through the same into stony bed with water - - -	30
	<hr/> 90

(30.) Horsington:—Well at the rectory.

Communicated by the rector.

	Ft.
Sand and gravel - - - - -	6
Stiff dark Boulder Clay - - - - -	15
Lighter marly Boulder Clay - - - - -	
	<hr/> 21

The water soaks in from the base of the gravel.

* Well-section communicated by Mr. James Freeborough, well-sinker.

† Communicated to Mr. A. J. Jukes-Browne by Mr. Chas. Wilkinson (well-sinker), Louth.

(31.) WOOD ENDERBY:—At Mr. Vintner's farm.

Information obtained on the spot.

	Ft.
White clay (Boulder Clay) with veins of sand near the bottom, and blue clay below - - -	30

(32.) TATTERSHALL PARK:—At farm three-quarters of a mile west-south-west of Park House.

Information from Mr. Patchett of Park House.

	Ft.
Soil and sandy gravel - - -	6
Clay with stones - - -	18
Sand and water - - -	1
	<hr/> 25

The well at Park House is dug and bored 30 feet through Boulder Clay, mottled blue and brown in colour, containing flints and pebbles of hard chalk.

(33.) HORNCastle:—Boring for water at the Great Northern Railway Station. Communicated by Mr. W. Kirby.

	Ft.
Grey and white chalky Boulder Clay - - -	44
Kimeridge clay - - -	91 +
	<hr/> 135

The boring was abandoned, as there was no prospect of obtaining water at a reasonable depth.

(34.) WOODHALL:—Not far from the church. Communicated by R. Harrison, of Woodthorpe, near Alford.

	Ft.
Clean clay with Ammonites - - -	33
Bored through same for - - -	70
	<hr/> 103

At a depth of 33 feet a spring of salt water was tapped, resembling that of Woodhall Spa, but it gradually became less salt, and was finally replaced by a supply of fresh water.

(35.) WOODHALL SPA:—At the School House. Communicated by Mr. Dobbs of Birkstead, well-sinker.

	Ft.
Sand and gravel, not bottomed - - -	18

(36.) WOODHALL SPA:—About 200 yards north-east of the Spa Hotel. Boring made in 1877?

Communicated to Mr. Cameron by J. Smalley of Hull (well-sinker).

	Ft.
Blue bind { Boulder Clay - - -	400
{ Kimeridge Clay - - -	
{ Oxford Clay - - -	
Blue bind, with beds of sandstone from 2 to 3 feet thick, and 12 to 14 feet apart - - -	120
	<hr/> 520

See also pp.

(37.) **WOODHALL MOOR** :—Well at the farm north-north-east of Tower-on-Moor.

Communicated by Mr. Dobbs of Kirkstead, well-sinker.

	Ft.
Clean yellow sand - - - - -	36
Gravel and shingle, no bottom - - -	6
	<hr/> 42

6. *On the Fens of the Witham.*

(38.) **MARTIN NORTH DROVE** :—At Mr. Sutterby's farm, 9 furlongs west of Kirkstead Ferry.

Communicated by Mr. Dobbs of Kirkstead, well-sinker.

	Ft.
Soil and turf - - - - -	1
Clean clay - - - - -	12
Turf with wood - - - - -	1
Clay - - - - -	2
Gravel and sand pierced for - - -	3
	<hr/> 19

(39.) **MARTIN NORTH DROVE** :—At Mr. Wilson's half a mile south-west of the last.

Communicated by Mr. Dobbs of Kirkstead.

	Ft.
Silt from the surface to - - - - -	14
Shingle below to - - - - -	0½
	<hr/> 14½

(40.) **METHERINGHAM FEN** :—At the farm one mile west-north-west of Metherringham Engine.

Information from Mr. Scholy, occupier.

	Ft.
Turfy soil - - - - -	1½
Clean clay - - - - -	12
Gravel and water - - - - -	?
	<hr/>
About -	15

(41.) **MARTIN FEN** :—At Mr. Goose's farm a mile west-south-west from Kirkstead Ferry.

Information from Mr. Dobbs, well-sinker, of Kirkstead.

	Ft.
Turfy soil - - - - -	1
Clean clay - - - - -	11
Turf with wood and trees - - - -	1
Clay - - - - -	4
Sand - - - - -	touched
	<hr/> 17

(42.) MARTIN FEN:—At Dobb's cottage half a mile from Kirkstead Ferry.

Information from Mr. Dobbs.

	Ft.
Soil and turf - - - - -	2
Clean clay - - - - -	11
Turf, with part of an oak-tree - - -	1
Clean clay - - - - -	1
Sand and shingle with rounded pebbles - - -	touched
	<hr/> 15

(43.) HARE BOOTH:—Three-quarters of a mile south-east of Southry Station.

Information obtained from the occupier (Mr. Wright).

	Ft.	In.
Black soil ("warp") - - - - -	0	10
Turfy layer, full of wood - - - - -	2	0
Silty clay, "mild and buttery" - - -	3	0
Gravel, with water at bottom - - -	5	0
Bluish clay, "stiff" (? Boulder Clay) - -	6	0
Quick-sand and water - - - - -	0	2
	<hr/> 17	<hr/> 0

7. On the Chalk Area.

(44.) LUDFORD WALK HOUSE:—Mr. W. Wingate's.*

	Ft.
White marl - - - - -	36
White chalk rock - - - - -	18
Red chalk - - - - -	6
	<hr/> 60

(45.) LUDFORD:—Farm about one mile north of.*

	Ft.
White chalk rock - - - - -	54
Red chalk - - - - -	6
Red sand [Carstone], about - - - - -	36
	<hr/> 96

(46.) CALSTHORPE:—South-west of Kelstern.†

	Ft.
White and black clay, "grey stone," and red sand -	66

(47.) LAMBCROFT:—A farm $1\frac{1}{2}$ miles north-north-east of Kelstern.†

Dug and bored through 240 feet of white chalk and "grey stone" (i.e., hard grey chalk).

(48.) WITHCALL HILL:—At the labourer's cottage by the farmstead on "Donnington Top."†

Dug and bored about 150 feet through chalk with two bands of pink chalk, and finding water in dark red chalk at the bottom. Another well at the farmstead, three-quarters of a mile north-east of Cold Harbour, is 165 feet deep, through the same beds.

* Well-section communicated by Mr. James Freeborough, well-sinker.

† Communicated to Mr. A. J. Jukes-Browne by Mr. Chas. Wilkinson (well-sinker), Louth.

MINERAL SPRINGS.

The Woodhall Spa Shaft and Bore-hole.

The following account of the Woodhall Spa was furnished to Dr. Granville by a physician resident at Horncastle :—

“In the year 1819, some speculators, under the idea of finding coal at Kirkstead, near Horncastle, caused a shaft to be sunk at that place, 100 yards deep; they then bored 100 yards deeper, when the works were discontinued, as it was stated, for want of money. Immediately on the discontinuance of this attempt, a gentleman, owning an estate in the parish of Woodhall, about a mile distant from Kirkstead, was induced, without previously boring, to sink a shaft thereon, of 280 yards in depth.

“Boring was then had recourse to, which was carried 120 yards deeper, when this scheme, like all the preceding ones, was abandoned as hopeless. In this trial no regular account was kept of the strata passed through, but from the information and specimens received, it appears that the sinking was commenced in the clunch clay, which was found to be 120 yards in thickness; they then passed in succession through forest marble, cornbrash, oolite, Bath freestone, lias, clunch clay again; then a rock, composed of carbonate of lime, siliceous sand, alumine, a greenish substance resembling chlorite, and a portion of mica, in which many terebratulæ were embedded. In this rock the sinking was discontinued. Of the boring no other account has been obtained than that they left off in a stone of light colour. A brine spring was found at about 170 yards deep, which was the only water met with.

“At present, the water, which is pumped up from a depth of 60 yards by iron pipes, and conveyed by pipes of the same material to a reservoir for distribution, becomes charged with the oxyde of that metal, which it possesses not in its natural state. The marble slabs in the bath are stained with the brown marks of the same.”*

Putting together this information with that above given, Mr. Jukes-Browne believes this boring to have gone through the following beds, and to have terminated in a sandstone belonging to the “*A. armatus* zone” of the Lower Lias.

	Ft.
Gravel and Boulder Clay	10
Kimeridge and Oxford Clay	350
Kellaway Rock, blue clays, Cornbrash limestone, Great Oolite Clay and Limestone, Upper Estuarine Clay	140
Lincolnshire Oolite and Northampton Sands	140
Lias (Upper, Middle, and part of the Lower)	380
	<hr/> 1,020 <hr/>

The spring of saline water issues at a depth of 530 feet, and would, therefore, appear to be situated in the Inferior Oolite. The shaft is said to be lined with brickwork to this depth.

Mr. Teague, who descended the well in March 1884, stated to Mr. Cameron that the water stands naturally at 50 feet from the surface, or at 330 feet from the surface when the pump is at work. Pumping carried on for 26½ minutes

* The Spas of England and Principal Sea-bathing Places, by A. B. Granville M.D., F.R.S. London, 1841, Chap. v., p. 104.

yielded 640 gallons, lowering the water from 50 to 52½ feet from the surface. The present machinery is capable of raising 1,000 gallons per hour, but is inadequate to drain the well.

An old prospectus, probably issued in 1864, contains the following analysis by Dr. Ziurek, of Berlin. (December 24, 1863.)

	Grains per gallon.*
Chloride of sodium - - - - -	1215·175
„ potassium - - - - -	2·453
„ magnesium - - - - -	86·846
„ calcium - - - - -	105·001
Bromide of sodium - - - - -	5·145
Iodide of „ - - - - -	2·731
Sulphate of soda - - - - -	30·628
Bicarbonate of soda - - - - -	45·765
Carbonate of lime - - - - -	9·381
„ iron - - - - -	0·277
Silica - - - - -	0·339
Organic matter - - - - -	trace.

From “The Woodhall Iodine Spa” (Thomas Wells, Proprietor).

In 1874 an analysis of the water was made for the Geological Survey by Dr. E. Frankland, F.R.S.,† and in 1883 the water was again analysed by Messrs. W. T. Wright and T. Burton,‡ the following results being obtained.

	Dr. Frankland, 1874. Parts per 100,000.	Messrs. Wright and Burton, 1883. Parts per 100,000.
Total solids in solution	2361·200	2020·0000 (at 100° C.)
„ „ after ignition	—	1820·0000
Organic carbon - - - - -	·372	—
„ nitrogen - - - - -	·532	—
Ammonium (NH ₄) - - - - -	·810	·6032
Albumenoid ammonia - - - - -	—	·0712
Nitrogen as nitrates and nitrites	·009	—
Total combined nitrogen - - - - -	1·208	—
Silica - - - - -	—	2·6457
Calcium - - - - -	—	54·9642
Magnesium - - - - -	—	27·9972
Iron - - - - -	—	·1300
Sodium - - - - -	—	608·9290
Potassium - - - - -	—	4·5652
Aluminium - - - - -	—	·7643
Chlorine - - - - -	1425·000	1111·3737
Bromine - - - - -	6·280	4·9729
Iodine - - - - -	·880	·5216
Sulphate - - - - -	—	11·1504
Carbonate, small, not exceeding	—	6·8541
Arsenic - - - - -	·016	nil.
Temporary hardness - - - - -	20·000	12·5557
Permanent do. - - - - -	245·000	184·2800
Total gases - - - - -	—	50·413 c.c. per litre.
Carbon dioxide - - - - -	—	27·414 „ „
Oxygen - - - - -	—	3·491 „ „
Nitrogen - - - - -	—	19·508 „ „
Temperature of the water	—	15·6° C.
Specific gravity at 15·5° C.	—	1·009177

* Grains per gallon correspond approximately to parts per 70,000.

† Geology of Fenland (Mem., Geol. Survey), p. 235, 1877.

‡ Journ. Chem. Soc., vol. xlv. (1884 Transactions), pp. 168-170.

The proportion of iodine and bromine in this water is greater (according to Messrs. Wright and Burton) than that in any other spring in Europe, excepting the spring of Challes, in Savoy, the water of which contains 1.045 parts per 100,000 of iodine.

The following remarks by Mr. West are quoted from Dr. Granville's *Spas of England*, chap. v., p. 111. "The chief peculiarity of this water is the abundance, as compared with others, of that active principal—iodine. It has been stated that the largest proportion before found in any British spring was one-tenth of a grain in a gallon.* In stating the present spring to yield about five times that quantity, I am guided by the most precise and delicate tests and experiments, detailed in my report The iodine in this water, *without concentration*, may be shown, with proper precaution, by starch and chlorine, a circumstance not recorded, as far as I am aware, of any other water in Britain."

"The total quantity of gases is very large; when fresh drawn up from a considerable depth, it is remarkable 'brisk,' and may be compared to Champagne wine. The quantity of carbonic acid is unusually large."

Dr. Granville states† that—" . . . the specimens of the water analysed were taken at a depth of 100 yards below the surface of the water, which is itself 50 yards below the mouth of the Well. The whole depth of the Well is about 170 yards, 17 or 18 feet of which is through a soft freestone rock, from whose surface brine-water has been seen to percolate constantly, by the person employed to go down to examine and arrange the pipes belonging to the pump. These pipes plunge about 25 yards below the surface of the water."

"Taken from the former depth in my presence, I found the water turbid or rather opalescent in its appearance; the taste was intensely briny, but neither bitter nor unpleasant. It is brisk and sparkling, and its temperature about 55°. Very faint indications of sulphuretted hydrogen were obtained by acetate of lead when the water was tested immediately, but none shortly after it was drawn."

The following remark on a chalybeate spring at the Monk's Abbey ruins, Lincoln, is taken from Dr. Granville's "*Spas of England*," p. 101:—"On evaporation, one pint contained $8\frac{3}{4}$ grains of solid ingredients, $1\frac{1}{2}$ being oxyde of iron, the remainder a combination of calcareous magnesia. The temperature of this spring was 51° F. Not many hundred feet westward of the 'Monk's Well,' apparently derived from the same ridge, is another very abundant stream At all times the water of this spring has 40° F., only of temperature, and has been used for many years for a cold bath."

At Welham, $1\frac{1}{2}$ miles east of Retford, there is a mineral spring, called St. John's Well, formerly celebrated as a cure for rheumatism and scorbutic complaints.

"At Cauntton, in a field adjoining the turnpike road and near the Mapplebeck bar, is a boiling spring . . . has been in existence a number of years, and never known to vary."‡

At North Willingham is a small spring from Kimeridge Clay, formerly believed to be beneficial for complaints of the eye.

* See Dr. Daubeny's Table of the iodine and bromine in certain mineral waters of Great Britain.—*I'vil. Trans.*, 1830.

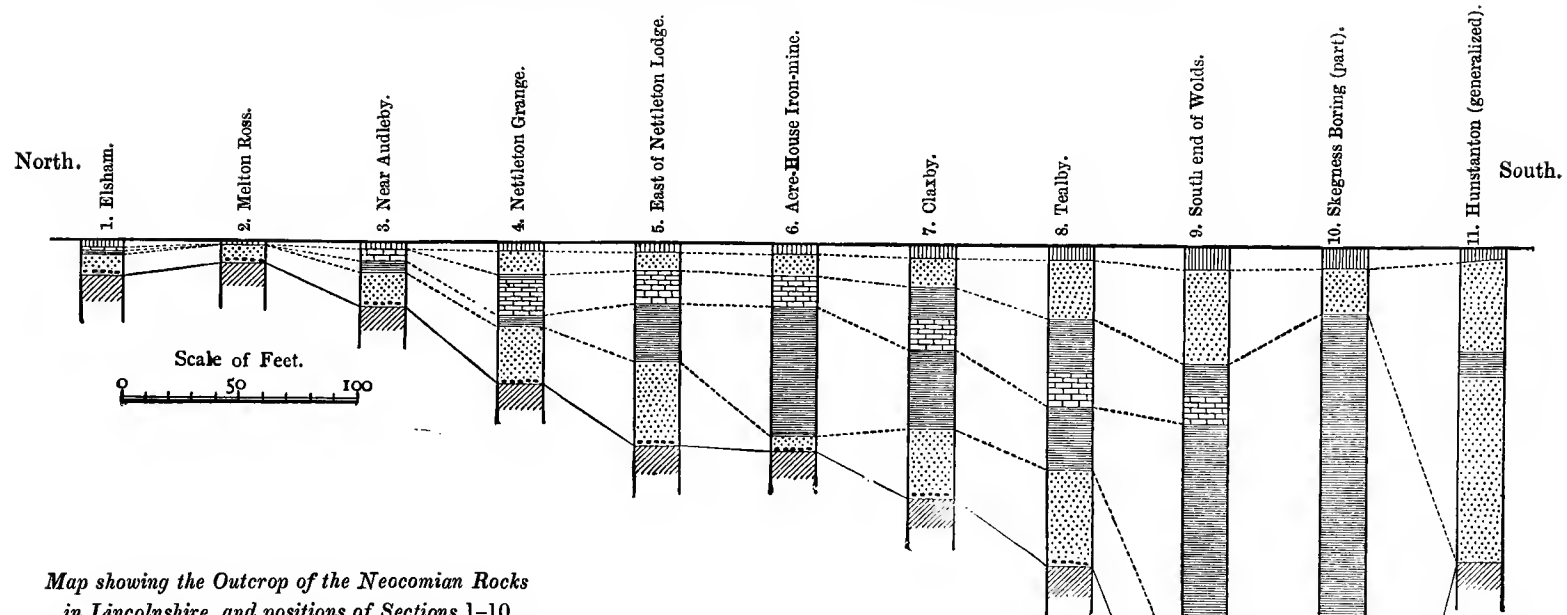
† "*Spas of England*," chap. v., p. 113.

‡ White's Directory. By "boiling" is probably meant bubbling.

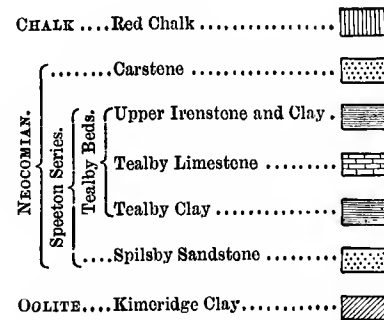
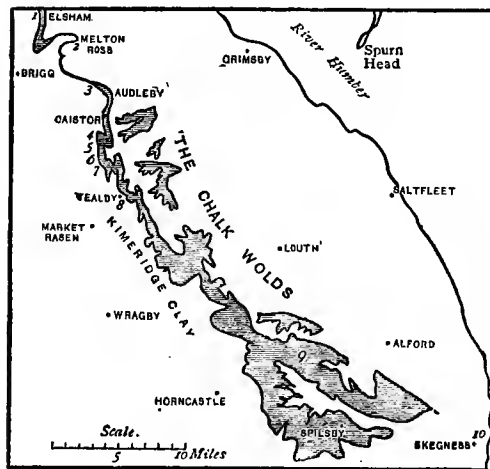
Comparative Sections of the Lincolnshire Neocomian Rocks from North to South.

By A. STRAHAN.

(Reproduced, by permission, from *Quart. Journ. Geol. Soc.*, vol. xlii., p. 492; 1886.)



Map showing the Outcrop of the Neocomian Rocks in Lincolnshire, and positions of Sections 1-10.



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